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APPLE SPRAYING AND DUSTING EXPERIMENTS 1918 TO 1924.

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BULLETIN 325

APPLE SPRAYING AND DUSTING EXPERIMENTS 1918 TO 1924.[1]

W. J. Morse and Donald Folsom.[2]

SUMMARY

(1) Tests in 1918, a rainy season, with three applications, gave better scab control with lime-sulphur than with lead arsenate alone; some scab control with lead arsenate alone, and leaf and fruit injury with calcium arsenate alone. A combination schedule of lime-sulphur for one application and lead arsenate alone for the others gave the highest percentage of smooth fruit. In the various plots, the amount of scab in the previous season seemed negligible in its effects.

(2) In 1919, a rather rainy season with scab appearing unusually early, the disease was not controlled well by three applications of 2-2-50 Bordeaux mixture or of lime-sulphur with lead arsenate, though it was controlled better by these than by lime-sulphur alone. A 2-10-50 Bordeaux mixture russeted the fruit, though not as badly as a 2-2-50, and controlled scab less. The 2-2-50 Bordeaux mixture caused more russeting in the calyx application than in the other two applications. In the various plots, the amount of scab in the previous season again proved negligible in its effects.

(3) In 1921, three applications of lime-sulphur spray controlled scab.

(4) In 1922, four applications of lime-sulphur with lead arsenate did not control scab well, though they did so better

[1]Previous experiments carried on from 1910 to 1917 are described in Bulletins 189, 198, 212, 223, 240, 252, 249 (summarizing the preceding six), and 271. By Morse, Bonns, and others.

[2]The senior writer was in charge of the experimental work reported herein from 1918 to 1923 inclusive, but the spray applications were supervised by Mr. Wellington Sinclair from 1921 to 1923. The junior writer assumed general charge in 1924 and is jointly responsible for the record made at harvest time in previous years. He is also responsible for the review of the literature and the conclusions drawn therefrom.

than four applications of dust or three applications of spray. Dry lime-sulphur was as effective as the liquid against scab, and caused less russeting. Guns were more effective than rods. Similar results were obtained with three kinds of dust—sulphur lead-arsenate, copper lead-arsenate, and copper calcium-arsenate.

(5) In 1923, five applications of lime-sulphur with lead arsenate in two of the five applications controlled scab well,—better than dust did. The kind of lime-sulphur, whether dry or liquid, and the use of a spreader or of a copper-sulphate dormant spray, appeared negligible in effects. In the various plots, the amount of scab in the previous season seemed to have no effect.

(6) In 1924, ascospores were mature and were being discharged at least as early as the time for the pre-pink application. Also, at this time some infection of leaves had occurred. At least two other periods of infection and incubation occurred in the check plots before August 15. These various infections were checked by the fungicides used. The early infection was checked, with leaf burning, by a schedule beginning with the pink spray application.

Scab on the fruit was controlled by four or five applications of lime-sulphur spray and by five applications of sulphur-lead arsenate dust. The amount of scab in any plot the preceding season had no effect. The use of a casein spreader increased the leaf burning caused by lime-sulphur, and was not needed for good control. Spraying caused more fruit dropping and russeting than was caused by dusting. Analysis of individual tree data also showed earlier leaf-fall with the use of a fungicide,—more with spray especially with a casein spreader or with the four-weeks application. The effect of tree variation was not great enough to hide a decrease of yield rate by spraying, this decrease being correlated with larger size of fruit. There were some correlations between scab, fruit-russeting, location of fruits on the tree, and degree of color.

Outside of the experimental area, but in the same variety and on the same farm, a combination schedule of two sprayings and four dustings, with no pre-pink application, controlled scab less than was the case in the experimental plots.

(7) The record for 14 years (1910 to 1919 and 1921 to 1924) on Highmoor Farm with Ben Davis gives May 19 as the average date for the pink application, June 4 as the average date for the calyx application, 50 per cent scab as the average for

check plots, and 8 per cent scab as the average for the plots with the best control by means of lime-sulphur spraying. A method of determining the profit from such control is presented. A three-application schedule that was effective from 1911 to 1916 inclusive failed in several subsequent years. Lime-sulphur seems to be the best general means for controlling apple scab. The dry form is usually as effective as the liquid when used strong enough. A "modified schedule" with lead arsenate substituted for lime-sulphur in the late applications has proved promising.

(8) Apple scab seems to be less injurious in Maine than in other apple growing regions. In regard to certain climatic conditions that determine the severity of scab injury, Maine is not exactly like any other region. It is more like the States to the southwest than it is like Nova Scotia. A review of reports on apple scab control in other regions indicates that the time of the first infection by the winter spores (ascospores) and the consequent value of a pre-pink application are exceedingly variable, that dusting is more often disappointing than spraying with the same number of applications and that the value of a casein spreader is easily overestimated. Some methods of applying the principles of scab control are suggested.

INTRODUCTION

Since the last bulletin was published on apple spraying, the data from several years' experiments have accumulated, involving altogether the one-season spraying of over 1200 trees and the individual examination of over 300,000 apples. The results of these experiments are given in the following pages, followed by an attempt to interpret their practical significance. Results from other stations and farms are considered in this practical interpretation.

EXPERIMENTS IN 1918.

As previously, the experimental plots were at Highmoor Farm, Monmouth, in the orchard known as "Ben Davis No. 2," which consisted of 555 trees. The trees, between 30 and 35 years old, had suffered from the preceding winter, and in the spring of 1918 alternate trees in each row were cut back rather severely and top-worked to McIntosh.

As in 1917, a Bordeaux mixture plot was considered unnecessary. Preceding experiments had shown that in spite of russeting in some seasons by a combination of lime-sulphur and lead arsenate, this treatment was usually effective in controlling scab and was profitable. From the results of the 1917 experiments, it was apparent that scab could not always be controlled by a series of three applications beginning with the pink-bud. A modification of the lime-sulphur and lead arsenate combination, increasing the lime-sulphur 20 per cent in the pink-bud application and using only double strength of lead arsenate in the other two applications, had controlled scab comparatively well with less russeting occurring. Tests had been made of the "T. P." arsenate of lead, of arsenate of lime, and of dry lime sulphur. In 1918 the experiments were planned primarily to test and compare different arsenicals in regard to their fungicidal value, both when used alone and when used in combination with lime-sulphur.[3]

Each plot consisted of 24 trees in a rectangular block four trees wide and six trees long. There were twelve plots. The treatment received by each is described in Table 1. Plots 1 to 7 were arranged side by side in one tier. Plots 8 to 10 were in a second tier adjoining plots 2 to 4 respectively. Plots 11 and 12 adjoined plots 9 and 10 respectively, forming a third tier. The first (pink-bud) application was made on May 19 (plots 1, 3, 5, 7, 10, 11 and 12) or on May 20 (plots 2, 4, 6, and 9) when the majority of the buds were showing pink. The second (calyx) application was made on June 4, and the third on June 25. A power sprayer was used,—one which was still being used satisfactorily in 1924 on another farm.

Prior to the first application, the latest rain was on May 14. Between the first and second applications rain fell at eight times, the total precipitation being 0.67 inch. Between the second and third applications rain fell at six times, totaling 4.75 inches.

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[3]For a recent discussion of arsenicals and their combination with fungicides, see Cook, F. C., and N. E. McIndoo. Chemical, physical, and insecticidal properties of arsenicals. U. S. Dept. Agri. Dept. Bul. 1147. 1923. See p. 2, 13-17. Also see Swingle, D. B., H. E. Morris, and Edmund Burke. Injury to foliage by arsenical spray mixtures. Jour. Agr. Res. 24:501-537. 1923.

The rainfall for May, June, July, August, and September was respectively 2.52, 4.80, 6.74, 6.00, and 8.86 inches. This was abnormally high except for May (see Table 11.)

In plot 8, unsprayed, scab was not apparent on June 4, but had appeared by June 13 on the leaves, and was common on both leaves and fruit on July 25. Scab also was more or less apparent on the leaves in the other plots. Leaf burning was marked only in plot 9, where arsenate of lime alone was used (see Table 1.) Here also the fall of fruit was heavy. The results obtained from the sorting of fruits are given in Table 1.

TABLE 1.

Results from sorting fruits in 1918.

Plot	Schedule[1]	Number of apples			
		Total	Smooth	Scabby[2]	Russeted[2]
			%	%	%
1	Lime-sulphur, 1.25-50[3]	8073	80	14	7
2	"Ortho" dry lead arsenate, 2-50	10490	50	49	1
3	"Ortho" dry lead arsenate and lime-sulphur, 1-1.25-50[4]	10699	72	19	10
4	"T.P." dry lead arsenate, 2-50	5053	45	54	1
5	"T.P." dry lead arsenate and lime-sulphur, 1-1.25-50	9798	70	21	11
6	Corona dry acid lead arsenate, 2-50	10265	56	44	1
7	Corona dry acid lead arsenate and lime-sulphur, 1-1.25-50	10200	64	22	16
8	Unsprayed check	10472	17	83	1
9	Dry calcium arsenate, 2-50	1577	77	22	2
10	Dry calcium arsenate and lime-sulphur, 1-1.25-50	2845	84	8	9
11	(1) Corona dry acid lead arsenate and lime-sulphur, 1-1.5-50; (2) and (3) Corona dry acid lead arsenate, 2-50	5584	86	12	2
12	Corona dry acid lead arsenate and commercial liquid lime-sulphur, 1-1.25-50	1626	79	2	19

[1]The three applications of each schedule (see p. 128 of text for dates) were made with the same type of mixture unless otherwise stated.
[2]Some apples were both scabby and russeted, being counted twice and thus making the total percentage sometimes appear to be more than 100.
[3]The first figure refers to gallons of 33° B. lime-sulphur concentrate, and the second figure to gallons of the made-up water solution.
[4]The three figures refer respectively to pounds of arsenate, gallons of lime-sulphur concentrate, and gallons of solution.

The best control of scab obtained was by no means perfect. Scab was controlled better where lime-sulphur was used alone or with an arsenate (in plots 1, 3, 5, 7, 10, 11, and 12, with scab on from 2 to 22 per cent of the fruits) and where arsenate of lime was used (plot 9, with scab on 22 per cent) than where arsenate of lead alone was used (plots 2, 4, and 6, with scab on from 44 to 54 per cent of the fruits). The differences between the last three plots probably are not significant. However, they show that arsenate of lead alone reduced the percentage of scabby fruits compared with the unsprayed plot (plot 8, with scab on 83 per cent of the fruits.)[4] The modified lime-sulphur schedule (plot 11) is included in the first group, which gave the best control. The value of the arsenate of lime alone as a fungicide (plot 9) unfortunately was counterbalanced by the injury to the leaves and fruit yield.

With the exception of the modified schedule, the greater fungicidal value of lime-sulphur over lead arsenate alone is somewhat compensated by the greater russeting of the fruits,—from 7 to 19 per cent as against about 1 per cent. Consequently there is a less marked difference between the lime-sulphur and lead arsenate schedules when the percentage of smooth fruits is considered. This smooth-fruit percentage, however, is lower (being 45 to 56 per cent) for the lead arsenate alone than for the lime-sulphur schedules (64 to 86 per cent). The highest percentage of smooth fruits (86 per cent) was obtained with the modified lime-sulphur schedule and the lowest (17 per cent) was obtained from the unsprayed check. The lower percentage of smooth fruits in plot 7 where one kind of lead arsenate was used with lime-sulphur, than in plots 3 and 5 where other kinds were used, probably is not significant.

The first ten plots were coincident with those of 1917 so that a comparison can be made, as to the amount of scab, between corresponding plots of the two years. This is done in Table 2. The check plot of 1917 (plot 9, with 98 per cent of scab) coincided with plot 9 of 1918 which had only 22 per cent scab. Three plots with about the same amount of scab in 1917 (plots 3, 8, and 10, with from 52 to 57 per cent scab) coincided

[4]As reported as early as 1911 by Errett Wallace, F. M. Blodgett, and Lex R. Hesler. Studies of the fungicidal value of lime-sulfur preparations. New York Cornell Agr. Exp. Sta. Bul. 290. 1911. See p. 175.

In Virginia in 1910, an accidental test showed that "arsenate of lead has some slight fungicidal value" against apple scab. (Reed, Howard S., J. S. Cooley, and J. T. Rogers. Foliage diseases of the apple. Report on spraying experiments in 1910 and 1911. Virginia Agr. Exp. Sta. Bul. 195. 1912. See p. 11.)

The initial results of this kind in Maine are described by W. J. Morse. Spraying experiments and apple diseases in 1913. Maine Agr. Exp. Sta. Bul. 223. 1914. See p. 13-16.

with plots in 1918 that varied from 8 to 83 per cent (plots 3, 8, and 10.) Therefore there seems to have been no obvious carry-over of plot difference from one year to the next. This refers only to the possible effect of the previous year's scab on the reliability of the experiment. It does not refer to the overwintering of scab and does not disprove the possibility that good control one year favors control the next year in commercial orchards throughout which the same spraying practice is used.

TABLE 2.

Comparison of 1917 plots with enclosed plots of 1918 and 1919.[1]

1917 plot		1918 plot		1919 plot	
No.	Scab	No.	Scab	No.	Scab
	%		%		%
1	73	1	14	1	33
2	82	2	49	2	33
3	57	3	19		
4	87	4	54	5	60
5	68	5	21	6	68
6	48	6	44		
7	45	7	22	9	82
8	52	8	83	10	39
9	98	9	22		
10	56	10	8	13	98

[1]Based on figures from Maine Agr. Exp. Sta. Bul. 271, Table III, and from Tables 1 and 3 of this bulletin.

EXPERIMENTS IN 1919.

In 1919 the comparison of different forms of lead arsenate was not attempted further, but lead arsenate was compared with arsenate of lime, in combination both with lime-sulphur and with Bordeaux mixture. The use of Bordeaux mixture was resumed because of the desire to test the 2-10-50 mixture. The modified lime-sulphur schedule was again tested and the addition of lime to the lead arsenate and lime-sulphur combination was tried. Single applications of Bordeaux mixture were made on three small plots to determine the time when this mixture produced russeting.

TABLE 3.

Results from sorting fruits in 1919.

Plot	Schedule[1]	Number of apples			
		Total	Smooth	Scabby[2]	Russeted[2]
			%	%	%
1	Dry acid lead arsenate and lime-sulphur, 1-1.25-50[3]	11358	67	33	[4]
2	Dry calcium arsenate and lime-sulphur, 1-1.25-50	8453	67	33	[4]
3	Dry calcium arsenate and lime-sulphur, 1-1.25-50, with 5 pounds stone lime	9866	58	42	[4]
4	Lime-sulphur 1.25-50	10077	37	63	[4]
5	(1) Dry acid lead arsenate and lime-sulphur, 1-1.5-50; (2) and (3) dry acid lead arsenate, 2-50	6883	40	60	[4]
6	(1) Dry calcium arsenate and lime-sulphur, 1-1.5-50; (2) and (3) dry acid lead arsenate, 2-50	9630	32	68	[4]
7	(1) One pound dry calcium arsenate in 2-10-50 Bordeaux mixture[5]; (2) and (3) dry acid lead arsenate, 2-50	8091	14	86	[4]
8	(1) Dry calcium arsenate and lime-sulphur, 1-1.25-50; (2) dry acid lead arsenate, 2-50; (3) as for (1)	12012	22	78	[4]
9	(1) One pound dry calcium arsenate in 2-10-50 Bordeaux mixture; (2) dry acid lead arsenate, 2-50; (3) as for (1)	7807	18	82	[4]
10	One pound dry calcium arsenate in 2-10-50 Bordeaux mixture	5764	35	39	30
11	One pound dry acid lead arsenate in 2-10-50 Bordeaux mixture	7442	44	37	22
12	One pound dry acid lead arsenate in 2-2-50 Bordeaux mixture	4449	24	26	57
13	Unsprayed check	2146	2	98	0
14-A	(1) One pound dry acid lead arsenate in 2-2-50 Bordeaux mixture; (2) and (3) omitted	2820	40	50	12
14-B	(1) Omitted; (2) as for (1) of plot 14-A; (3) omitted	2826	17	61	33
14-C	(1) and (2) omitted; (3) as for (1) of plot 14-A	2668	27	71	5

[1]The three applications of each schedule (see p. 132 of text for dates) were made with the same type of mixture unless otherwise stated.
[2]Some apples were both scabby and russeted, being counted twice and thus making the total percentage sometimes appear to be more than 100.
[3]The three figures refer respectively to pounds of arsenate, gallons of lime-sulphur concentrate (33° B.), and gallons of the made-up water solution.
[4]Less than one-half of one per cent.
[5]The three figures refer respectively to pounds of copper sulphate, pounds of lime, and gallons of the made-up water mixture.

With the exception of the three small plots, each plot consisted of 18 trees in a rectangular block three trees wide and six trees long. There were 13 large plots. The treatment received by each is described in Table 3. Plots 1 to 9 were arranged side by side in one tier. Plots 10 to 13 were in a second tier adjoining plots 2 to 5 respectively. The three small plots adjoined plots 1 and 10. The first (pink-bud) application was made on May 19 (plots 1, 2, 4, and 8) or on May 20 (plots 3, 5 to 7, 9 to 12, 14-a, 14-b, and 14-c.) The second (calyx) application was made on June 6, and the third on June 21.

In May prior to the first application, rain fell at eight times (May 2, 4, 5, 7, 11, 12, 17, and 18), with a total precipitation of 3.19 inches. Between the first and second applications rain fell only on May 21, 22, 23, and 26, totaling 1.89 inches. Between the second and third applications rain fell at four times, totaling 0.67 inch. The rainfall for May, June, July, August, and September was respectively 5.08, 1.09, 2.71, 2.89 and 5.72 inches. This was below normal except for May and September (see Table 11.)

In plot 13, unsprayed, scab was not apparent on May 28 but was common on the leaves by June 5. This was unusually early (see Table 10, sixth column). The fruits were practically all scabby on July 30, and the set of fruit was much less by August 30 than in adjoining plots. Scab was also common on the leaves by June 5 in plots 7 to 13, and present in plots 1 to 6. This difference may be due in part to location, inasmuch as plots 2 and 8, though differing in scab at this time, had previously received the same treatment (see Table 3.) Later in the summer, scab on the leaves remained inconspicuous in plots 1 to 3, where a combination of lime-sulphur and an arsenical was used three times. Scab increased in plots 4 to 6, where such a combination was used only once or not at all. It became less conspicuous in plot 8, where such a combination was used twice, and in plots 10, 11, and 12, where a combination of Bordeaux mixture and an arsenical was used three times. It remained conspicuous in plots 7 and 9, where 2-10-50 Bordeaux mixture in combination with an arsenical was used less than three times, and in plot 13, which was the unsprayed check. It seems that the initial scab infection occurred unusually early on the leaves throughout the orchard, with some difference in severity correlated with location in the orchard rather than with spray schedules, and that the various spray schedules differed in their value for checking scab infection thus started. Probably the first infection occurred during the rainy period May 2 to 18, before the time of the first spray application.

Leaf burning and spotting were bad only in plots 12, 14-A, 14-B, and 14-C, where 2-2-50 Bordeaux mixture was used once or oftener.[5] In plots 14-A and 14-C, each sprayed once with this Bordeaux mixture, the leaf injury did not appear until about two weeks had elapsed after the application, and the russeting of the fruit was delayed still more. The results obtained from the sorting of fruits are given in Table 3.

Scab was controlled best by 2-2-50 Bordeaux mixture applied three times (plot 12, with scab on 26 per cent of the fruits). It was controlled nearly as well by lime-sulphur combined with an arsenical (plots 1 and 2, with scab on 33 per cent of the fruits.) Scab was controlled less by 2-10-50 Bordeaux mixture (plots 10 and 11) and by the lime-sulphur and arsenical combination with lime added (plot 3).[6] Scab control was markedly poorer with the use of lime-sulphur without an arsenical (plot 4)[7] and where lime-sulphur or Bordeaux mixture was applied only once or twice (plots 5 to 9, and 14). The percentage of scab in the best plot (plot 12, with 26 per cent scabby) was high, considering that Bordeaux mixture was used. It was higher in plot 1 with lead arsenate and lime-sulphur (33 per cent) than in the 1918 series (Table 1, plot 7, with 22 per cent scabby) where the same mixture was used. These facts, together with the early appearance of scab, indicate that the times of application were not sufficiently early or frequent. It is therefore possible

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[5]The calcium-arsenate combination with lime-sulphur, though causing no injury here in 1918 or 1919, caused foliage injury in Michigan, especially on Ben Davis. (Dutton, W. C. Dusting and spraying experiments of 1918 and 1919. Michigan Agr. Exp. Sta. Special Bul. 102. 1920. See p. 24.)

Chemical changes take place when acid lead arsenate and lime-sulphur are mixed. This mixture is therefore incompatible chemically. Calcium arsenate when mixed with lime-sulphur, is chemically compatible and would seem to be a satisfactory insecticide. Field experience, however, shows that it often injures the foliage sprayed. (Cook, F. C., and N. E. McIndoo. *Op. cit.*, p. 16.)

[6]In Massachusetts likewise "the indications are that the addition of lime to the lime-sulphur-lead arsenate combination spray reduces somewhat the fungicidal efficiency of the latter." (Doran, William L., and A. Vincent Osmun. Combating apple scab. Spraying and dusting experiments in 1923 with summary of three years' results. Massachusetts Agr. Exp. Sta. Bul. 219. 1924. See p. 9.)

[7]As reported as early as 1911 by Errett Wallace, F. M. Blodgett, and Lex. R. Hesler. (*Op. cit.*, p. 174 and 178.) Similar results were obtained in experiments conducted in 1911 and 1912 by Pickett *et al.* (Field experiments in spraying apple orchards. Illinois Agr. Exp. Sta. Bul. 185. 1916. See p. 198.)

that some of the other schedules were unsatisfactory because of the times of spraying rather than because of the types of mixture employed.

There was no russeting except with Bordeaux mixture. Increasing the lime content in this mixture reduced the russeting somewhat but not enough (plots 10-12).[8] More russeting resulted from the second (calyx) application than from the first (pink) or third.[9] The highest percentage of smooth fruits was obtained with lead arsenate and lime-sulphur (plots 1 and 2), but the percentage was too low for the season's results to be satisfactory from the standpoint of control.

The series of plots was in the same place as that for 1918. Although the plots were smaller in 1919 than in 1918, in the 1919 series there were seven plots each of which lay entirely within a plot of the 1918 series, and a comparison can be made, as to the

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[8]In Massachusetts "a 3-10-50 home-made Bordeaux mixture used alone for all applications russeted the fruit and burned the foliage so badly that its use in this way will be discontinued." (Krout, Webster S. Combating apple scab. Spraying and dusting experiments in 1922. Massachusetts Agr. Exp. Sta. Bul. 214. 1923. See p. 33.)

In Virginia, 2-10-50 Bordeaux mixture has produced serious russeting. (Reed, Howard S., J. S. Cooley, and J. T. Rogers. *Op. cit.*, p. 19).

[9]Thus giving confirmation, for local conditions, of the statement made in 1907 by U. P. Hedrick that "Bordeaux injury on fruit comes from early spraying, after the blossoms have dropped." (Bordeaux injury. New York Agr. Exp. Sta. Bul. 287. 1907. See p. 110.)

In Virginia, on Ben Davis "the worst russet is produced by the first two applications of the spray mixture after blossoming. (Reed, Howard S., J. S. Cooley, and J. T. Rogers. *Op. cit.*, Fig. 11.)

In the report of the Hood River Branch Experiment Station of Oregon for 1913-1914, H. S. Jackson and J. R. Winston state that "as has been the experience in most other sections of the country, considerable injury followed the use of Bordeaux when used in the calyx or 'Ten days' spray" (see p. 6.)

J. Ralph Cooper reports that "the earlier in the season Bordeaux is used after the trees come into full bloom, the greater will be the danger of injury from spray burn." He refers to russeting; the earlier applications were additional applications, so that the effect of one application was not determined. (Spraying experiments in Nebraska. Nebraska Agr. Exp. Sta. Res. Bul. 10. 1917. See p. 41.) He found it satisfactory before blooming, however.

In Missouri, "for the calyx spray, bordeaux is apt to russet the fruit badly. When used in 10 days after the calyx spray it often does considerable damage." (T. J. Talbert. Apple blotch control in Missouri. Missouri Agr. Exp. Sta. Circ. 124. 1924. See p. 5.)

amount of scab, between corresponding plots of the two years. This is done in Table 2. The plot with the least scab in 1918 (plot 10) contained the plot with the most scab in 1919 (plot 13). Three plots with scab varying in 1918 from 14 to 83 per cent (plots 1, 2, and 8) contained very similar plots in 1919 (plots 1, 2, and 10), with from 33 to 39 per cent of scab. There again seems to have been no obvious carry-over of plot difference from one year to the next. (See p. 130.)

1920 AND 1921.

No spraying experiments were conducted in 1920. In 1921, spraying was done with a lime-sulphur lead arsenate mixture, using a new Bean Giant Triplex machine. The pink application was made on May 6 and 7, the calyx application on May 24 to 26, and the third application on June 13-14. Unsprayed check trees produced fruit of which about 25 per cent was scabby. The percentage was about 5 for the sprayed lot examined.

EXPERIMENTS IN 1922.

In 1922 a comparison was made between three kinds of dust, liquid lime-sulphur, and dry lime-sulphur, each applied four times, with arsenate in the liquid preparations except at the first application and in all the dust. Comparison was also made between guns and rods applying liquid lime-sulphur at three times, with arsenate present. A new Niagara power duster was used. Each plot consisted of either 24 or 48 trees, in two equal rows (see Chart 1) in the orchard known as "Ben Davis No. 1." Though different in location from the trees used in 1918, the trees were similar in age. The dates of the applications and the materials applied are given in Table 4. The trees are recorded as having reached the pink-bud stage on about May 17, and the calyx stage on about May 22.

In plot 4, unsprayed, scab became common on the foliage, which also showed some marginal injury. Leaf injury was also shown by all the dusted and sprayed plots, as might be expected from the behavior of the check. Scab was observed on the foliage in all the plots, plot 6 (sprayed three times with rods) showing more than plot 3 (sprayed three times with guns.) The fruits

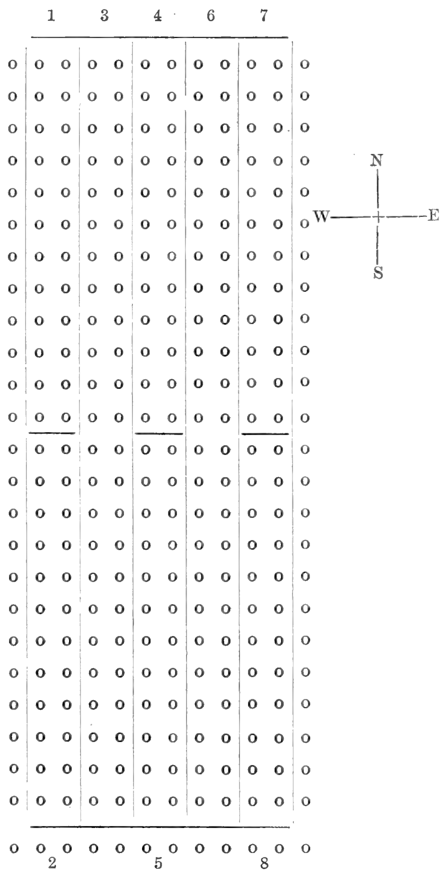

Chart 1. Arrangement of the plots in the 1922 series. Each letter represents a tree. The numerals refer to the schedules followed (see Table 4.)

were gathered, for sorting, only from the inner half of each tree, that is, from the half or side next to the aisle between the two rows of the plot. The results obtained from the sorting are given in Table 4.

Scab was controlled best by lime-sulphur spray containing lead arsenate, and applied four times with rods. Here the dry lime-sulphur (plot 8) was somewhat better (17 per cent of the fruits being scabby) than the liquid (plot 7) in respect both to scabbiness and to russeting, so that it gave the highest percentage

TABLE 4.

Results from sorting fruits in 1922.

Plot	Schedule	Number of apples			
		Total	Smooth	Scabby[1]	Russeted[1]
			%	%	%
1	May 12[2], May 22, June 5, and June 28, B-1 dust.[3]	5505	52	41	7
2	May 12, May 22, June 5, and June 27, B-8 dust[4], except B-1 dust[3] on May 22	621	48	46	7
3	May 17, May 27, and June 24, dry lead arsenate and lime-sulphur 1.5-1.25-50[5] with guns	8624	54	37	10
4	Unsprayed check	4553	23	76	1
5	May 12, May 22, June 5, June 27, B-9 dust[6], except B-1 dust[3] on May 22	1271	50	38	13
6	May 17, May 27, and June 24, dry lead arsenate and lime-sulphur 1.5-1.25-50 with rods	5057	30	68	2
7	May 13, May 23, June 3, and June 27, dry lead arsenate and lime-sulphur, 1.5-1.25-50, with rods	3204	66	19	16
8	May 12, May 24, June 3, and June 24, dry lead arsenate and Sherwin-Williams dry lime-sulphur, 1.5-4-50[7], with rods	2091	76	17	7

[1]Some apples were both scabby and russeted, being counted twice and thus making the total percentage sometimes appear to be more than 100.
[2]For the condition of the blossoms on different dates see text p. 136.
[3]Consists of 90 parts sulphur and 10 parts lead arsenate.
[4]Consists of 10 parts anhydrous copper sulphate, 10 parts lead arsenate, and 80 parts lime.
[5]The three figures refer respectively to pounds of arsenate, gallons of lime-sulphur concentrate, and gallons of solution.
[6]Consists of 13 parts anhydrous copper sulphate, 8 parts calcium arsenate, and 79 parts lime.
[7]The three figures refer respectively to pounds of arsenate, pounds of dry lime-sulphur, and gallons of made-up water mixture.

of smooth fruits of all the plots.[10] On each dust plot a 90-10 sulphur lead-arsenate mixture was used at the calyx application, while at the three other applications this mixture was used in plot 1 only, plot 2 having a 10-10-80 copper-sulphate lead-arsenate mixture, and plot 5 having a 13-8-79 copper-sulphate calcium-arsenate mixture. The three dust plots produced fruits of which from 38 to 46 per cent were scabby.[11] With liquid lime-sulphur spray containing lead arsenate applied three times, the guns (plot 3) gave much better scab control (37 per cent of the fruits scabby) than the rods (plot 6, with 68 per cent of the fruits scabby) and produced somewhat more russeting, both possibly because of greater thoroughness in application. There was not much difference between the rod-sprayed (3 times) plot and the unsprayed check (plot 4).

[10]See p. 30 for a general discussion of dry lime-sulphur.
[11]See p. 176 for a general discussion of dusting.

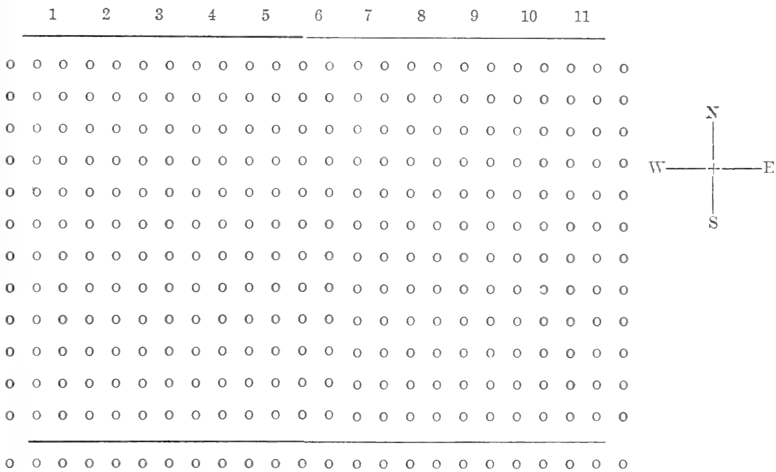

Chart 2. Arrangement of the plots in the 1923 series. Each letter represents a tree. The numerals refer to the schedules followed (see Table 5.)

EXPERIMENTS IN 1923.

In 1923 a further comparison was made between liquid lime-sulphur and the dry, and between two kinds of dust. A test was made also of the effect of spreaders and of a copper-sulphate dormant spray. All spray applications were made with guns. Each plot consisted of 24 trees in two equal rows (see Chart 2.) The dates of the applications and the materials applied are given in Table 5. The trees reached the pink-bud stage on about May 24, and the calyx application was made on June 7. The fruits were gathered completely from the inside halves of the trees as in 1922, but only five barrels from each plot, selected at random in the sorting-shed, were examined. The results obtained from the sorting are given in Table 5.

The applications on plots 1, 2, 4, 5, and 6 were all made on the same five dates. Here the dry lime-sulphur[10] (plots 1 and 5, with 6 and 7 per cent scab) controlled scab about as well as the liquid (plot 6, with 5 per cent scab.) With liquid lime-sulphur, the copper-sulphate dormant spray (plot 2, with 9 per cent scab) did not reduce scab as compared with the results in plot 6, and the addition of the Kayso spreader[12] (plot 4, with 4 per cent scab) made no marked difference.

TABLE 5.

Results from sorting fruits in 1923.

Plot	Schedule[1]	Number of apples			
		Total	Smooth[2]	Scabby[2]	Russeted[2]
			%	%	%
1	May 19[3], June 7, June 25, July 17, and August 6, dry lime-sulphur 4-50[4]	3803	93	6	1
2	May 19, June 7, June 25, July 17, and August 6, liquid lime-sulphur 1.25-50[5]. Preceded by copper-sulphate dormant spray.[6]	3483	89	9	1
3	Unsprayed check	4055	41	58	1
4	May 19, June 7, June 25, July 18, and August 6, liquid lime-sulphur 1.25-50, containing Kayso spreader	3548	92	4	4
5	May 19, June 7, June 25, July 17, and August 6, dry lime-sulphur 4-50	3323	89	7	5
6	May 19, June 7, June 26, July 17, and August 6, liquid lime-sulphur 1.25-50	3093	92	5	3
7	May 24, June 7, June 26, July 18, and August 6, dry lime-sulphur 4-50	3265	91	3	5
8	May 24, June 7, June 26, July 2, and August 8, B-1 dust.[7]	3898	72	25	3
9	May 24, June 7, June 26, July 2, and August 8, B-8 dust.[8]	3754	80	19	1
10	May 21, June 7, June 25, July 18, and August 6, liquid lime-sulphur 1.25-50. Preceded by copper-sulphate dormant spray.[6]	3693	96	1	3
11	May 21, June 7, June 25, July 17, and August 6, liquid lime-sulphur 1.25-50 containing Spracein spreader.	3669	96	1	4

[1]All spray applications made with guns, with lead arsenate in the mixture used for the second and third applications.
[2]Non-inclusion of fractions of percentages sometimes results in these not totaling 100.
[3]For the conditions of the blossoms on different dates see text p. 139.
[4]The first figure refers to pounds of lime-sulphur, and the second figure to gallons of made-up water solution.
[5]The first figure refers to gallons of 33° B. lime-sulphur concentrate, and the second figure to gallons of made-up water solution.
[6]Five pounds of copper sulphate in 50 gallons of water; applied also to the dead leaves on the ground.
[7]Consists of 90 parts sulphur and 10 parts lead arsenate.
[8]Consists of 10 parts anhydrous copper sulphate, 10 parts lead arsenate, and 80 parts lime.

The applications on plots 10 and 11 were made about like those discussed in the preceding paragraph, except that they were begun two days later. Here there was less scab (1 per cent) than in the corresponding plots described above, both with the copper-sulphate dormant spray and with a spreader. How much the difference is due to the time of application, the kind of spreader,

[12]See p. 182 for a general discussion of casein spreaders.

or chance, is an open question. Possibly the range of scab percentage got in these plots, from 1 to 9 per cent, is due to chance in uncontrolled factors. The same explanation may hold for plot 7 where, with a later first application, dry lime-sulphur seemed to control scab better (3 per cent) than was done in plots 1 and 5.

The schedule for the dust plots (8 and 9, with 25 and 19 per cent scab) was like that for plot 7, except for the fourth application. Possibly the longer interval between the fourth and fifth applications in the dust plots was responsible for the poorer degree of control. The copper dust gave somewhat better control than the sulphur dust.[11]

Since russeting ranged from 1 to 5 per cent, with these extremes recorded for two plots (1 and 5) that had received the same treatment, no definite conclusions can be drawn about this effect. With only 41 per cent of the fruits smooth in the unsprayed check plot, the percentage of smooth fruits was about 90, or above, in other plots except the dusted ones. This encouraging result indicates that five applications are more efficient than three or four as made in 1922, when the unsprayed check plot gave 23 per cent smooth fruits and none of the treated plots gave over 76 per cent smooth fruits.

TABLE 6.

Comparison of 1922 plots with included plots of 1923, and of 1923 plots with included plots of 1924.[1]

1922 plots		1923 plots		1924 plots	
No.	Scab	No.	Scab	No.	Scab
	%		%		%
1	41	5	7	1-N	3
3	37	6	5	2-N	49
4	76	7	3	3-N	3
6	68	8	25	4-N	5
7	19	9	19	5-N	3
----------	----------	10	1	6-N	2
----------	----------	11	1	7-N	2

[1]Based on figures from Tables 4, 5, and 7.

Five of the plots in the 1923 series were included in, or were identical with, plots of the 1922 series. A comparison as to the scab percentage is made in Table 6, where it is shown that there was no apparent carry-over, but that the 1923 treatment was the determining factor. For example, plots 4 and 6 in 1922 were both about equally high in scab, but the corresponding plots in 1923 were at the extremes. Again, between plots 6 and 7 of 1922 there was a difference of about 50 per cent, but only 6 per cent difference between the corresponding plots of 1923.

EXPERIMENTS IN 1924.

At the beginning of this season it was thought that spray guns and rods had both been shown to be efficient practically, and that choice between them should depend upon the size of the power outfit needed and afforded by the orchard grower. Also, it was thought that the choice between the home-made, the commercial liquid, and the commercial dry form of lime-sulphur depended upon the user's preferences regarding expense and convenience rather than upon any difference in effectiveness. The questions that seemed most important for experimental work were those of the effects of dusting, the effects of using a casein spreader, and the relationship of the life history of the fungus to the times of spraying. Seven schedules were followed, each on duplicate plots. One pair of plots received five sprayings beginning with the delayed dormant. Two pairs of plots received five sprayings beginning with the pre-pink, one with a spreader and the other without. Corresponding to these was a dusted pair of plots, also with five applications beginning with the pre-pink. Two pairs of plots received four sprayings, beginning in one pair with the pre-pink and in the other with the pink. There was one check pair with no fungicide or insecticide applied during the season. The arrangement and numbers of the plots are given in Chart 3. The schedule followed and materials used for each plot are given in Table 7, where each general time of application is numbered with the delayed dormant designated as the first. Spray guns were used throughout the season, usually with a pressure of from 250 to 300 pounds. The labor situation was such that during the season six different persons worked with the spray guns, some without having had much previous experience and some even without the ability to detect the change in the appearance of the shoots that immediately follows the application of the spray. Few if any of the trees were 25 feet high, so that there was less danger from missing the top branches than from excessive spraying of the lower branches. Many trees were partly dead or scantily leaved because of winter-killing of a part of the trunk occurring several years previously. There was no interlacing of branches of adjacent trees.

The delayed dormant application was made on May 10 when the leaf buds were breaking open, some buds having the leaf tips showing green and others barely breaking. The wind was moderate at the time of spraying.

When the first search was made in the dead leaves from the preceding season for mature ascospores (winter spores) of the scab fungus, on May 13, some were found that were mature and that were discharged as soon as the containing perithecia were immersed and broken up in water. Discharged ascospores were also found on a glass slide left, during a rain, just above a leaf which had been replaced upon the soil after having been found to contain mature spores, and on a vaselined glass slide placed in a tree under which scabby leaves were lying on the ground. In this way it was shown that ascospores were being discharged before the time for the pre-pink application, made on May 19-20.[13] Rainfall recorded at Highmoor Farm at this time was 2.44 inches on May 1, 0.35 inch on May 4, 2.33 inches on May 13, 0.24 inch on May 14, and 0.01 inch on May 18.

The pre-pink application was made on May 19 with the spray and on May 20 with the dust, with no rain intervening between spraying and dusting. The leaves from many blossom-cluster buds were over an inch long with the blossom buds still unseparated in the cluster. Some buds were still in the delayed dormant stage while some blossom buds were pink. During spraying the wind was strong, blowing the spray more or less through several rows of trees other than the plot which was being sprayed. This was found later to have no apparent effect on scab percentages in plots receiving the drift. During dusting, which was always done as soon as possible after daybreak during the season, it was calm. The dust was applied from only one side of each row of trees. An examination of the leaves on

[13]Such early ascospore discharge is common in the United States, according to various publications, reports, and letters seen by the writers.
For a general discussion of the pre-pink application see p. 172.

May 20 showed that the spray had been applied less uniformly and thoroughly than the dust, probably because of the greater wind occurring at the time of application.

Following the example of Wallace[14] and Cooper[15], on May 20 large paper sacks were tied over some branch ends. The leaves thus enclosed showed scab when uncovered on June 12, the same as unbagged branches, indicating that scab had infected the foliage before May 20. The source of infection could have been ascospores, according to the observations described previously, probably causing infection on May 13. The ascospores are considered to be generally the chief source of primary spring infection. On May 24, following a rain, many ascospores had been caught on a slide fastened over a leaf, and where these were in condensed water a high percentage were germinating. By this time the dust seemed to have been washed off or washed into the depressions in the leaves.

The pink application was made on May 30. Although some blossom buds had not separated in the cluster (and in fact a few buds did not open until after the time of the calyx application on June 13) on May 30 postponement was made inadvisable by the opening of some of the blossoms. During dusting it was moderately windy and there was no dew. Dust was applied from one side of each row at the rate of about 2⅓ pounds to a tree (total consumption estimated.) In applying dust, the writer preferred to err on the side of liberality rather than scantiness. During spraying the wind was strong.

Scab was first noted on the leaves about June 11, being then in small spots up to ¼ inch in diameter and only one or two to a leaf. About 3 per cent of the leaves were thus infected in the unsprayed check plots, somewhat fewer in the dusted plots, and practically none in the sprayed plots, according to a superficial examination of the leaves on the trees. According to the bagging experiments previously described, this infection occurred at or before the time at which the pre-pink application was made, and according to the observations on ascospore ripening and rainfall could have occurred as early as May 13.

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[14]Wallace, Errett. Scab disease of apples. New York (Cornell) Agr. Exp. Sta. Bul. 335. 1913. See p. 573.

[15]*Op. cit.*, p. 36.

The calyx application was made on June 13. During dusting there was dew, fog, and a slight drift of air. The dust was applied from one side of each row at the rate of about three pounds to a tree. During spraying the wind was moderate, and the materials were applied at the rate of about five gallons to a tree.

By June 26 the amount of scab readily apparent on the leaves had increased slightly in all plots. Wind had interfered with thoroughness of spraying and dusting in the pink and previous applications. Where no pre-pink had been applied, so that no fungicide was present for some time after scab infection began, instead of more scab there were more large burned spots than on the other sprayed plots. Probably burning occurred where scab infection had occurred, as has been suggested as sometimes happening, by Crandall,[16] Wallace,[17] Stewart,[18] Watkins,[19] Morse and Yeaton,[20] and Cooper.[21] If so, it probably resulted from the calyx spraying rather than from the pink spraying.

The "two-weeks" application was made on June 27. During dusting there was a slight drift of air. The dust was applied from one side of the row. During spraying the wind was slight, and the materials were applied at the rate of about five gallons to a tree. Although the pressure was over 300 pounds with one gun being used and often from 250 to 300 pounds with two guns in action, sometimes two guns reduced the pressure to below 250 pounds and prevented any overflow back into the tank. Comparative inefficiency of gun-spraying under such conditions has been claimed by Childs.[22]

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[16]Crandall, Charles S. Bordeaux mixture. Illinois Agr. Exp. Sta. Bul. 135. 1909. See p. 221: "There may be an early and abundant infliction of apple scab and after it there is great certainty of serious brown spotting from spraying."

[17]Wallace, Errett. Spray injury induced by lime-sulphur preparations. New York Cornell Agr. Exp. Sta. Bul. 288. 1910. See p. 106, 123, and 136.

[18]Stewart, F. C. Notes on plant diseases, I. New York Geneva Agr. Exp. Sta. Bul. 328. 1910. See p. 315.

[19]Watkins, O. S. Tests of lime sulphur, Bordeaux mixture and other sprays. Illinois Agr. Exp. Sta. Circ. 159. 1912. See p. 7 and 10.

[20]Morse, W. J., and G. A. Yeaton. Orchard spraying experiments in 1912. Maine Agr. Exp. Sta. Bul. 212. 1913. See p. 64.

[21]*Op. cit.*, p. 76.

[22]Childs, LeRoy. Spray gun versus rod and dust in apple orchard pest control. Oregon Agr. Exp. Sta. Bul. 171. 1920. See p. 27-30.

On July 8 scab had increased noticeably on the leaves in the unsprayed check plots, but not elsewhere. In the checks there were often several to many spots on a leaf, many being on the upper surface. This increase probably was due to dissemination of summer spores from the spots noted on June 11. On June 13 the foliage in the sprayed and dusted plots had been protected by the calyx application, this accounting for the absence of increase of scab in them.

The "four-weeks" application was made on July 9. During dusting there was a slight wind and the leaves were wet from a rain. Dust was applied from both sides of each row, at the rate of about 3 pounds to a tree. During spraying the wind was slight, and the materials were applied at the rate of about three gallons to a tree. The application on plots 3-N, 3-S, 7-N, and 7-S was made with a small one-gun sprayer with a pressure of about 200 pounds, the large machine being in need of repairs.

General observations on August 1 showed no increase of scab on the leaves, but considerable increase on the fruits, in the check plots. Here it was estimated that about 25 per cent of the fruits were infected. By August 15 some new scab on the leaves, consisting of small spots, had become evident and the disease was more conspicuous on the fruits, of which about 40 per cent were infected, sometimes with spots only about 1/25 inch in diameter.[23]

It seems from the foregoing account that there was some early scab infection in all plots, but that it was checked in the plots other than the unsprayed check. In the latter, at least three periods of infection and incubation had occurred by August 15. Although the first infection occurred before some plots were sprayed, and before any plot was sprayed or dusted thoroughly, scab was checked by spray or dust even when not begun until May 30 at the pink stage, as was the case with one spray schedule.

Burning of the leaves was worse in the plot where the delayed dormant was applied and where the casein spreader was used. Fruit drop at the time of petal fall was less pronounced

[23]Although this field estimate happened to be exactly the average of the scab percentage of the check plots, as determined by sorting after picking, the field estimates for various check-plot trees were sometimes over 10 per cent (absolute, not relative) in error. The greatest part of the scab on sprayed and dusted trees was undetected when field estimates were made.

on the dusted and check plots than on the sprayed plots.[24] On the dusted and check plots some fruits were starved off later, but a difference was still evident on August 15, between these and the sprayed plots.[25]

On August 28 five trees were selected in each plot which apparently were the ones with the most apples on the inside half of the tree—that is, on the half next to the aisle through the plot. The location of the count trees is given in Chart 3, where each of them is represented by a capital letter. Tree "E" is not given in plot 6-N because the picked fruit was misplaced and lost among the commercial stocks of the Farm. Two extra trees were selected in plot 2-S (check), at the end next to a sprayed plot, to test the effect of greater exposure to wind-blown spray. (See p. 155 for the scab percentage, which was about the same as the plot mean.) On September 30, the day before the sorted fruit was picked, each of the 71 count trees was observed on the inside or count half of the tree, as to the relative number of leaves, the location and color of the fruits, and in some cases as to the probable percentage of scabby apples. The fruit from each tree was kept and sorted separately. Record was made of the yield in estimated tenths of barrels, of the total number of fruits, of the number scabby and russeted, and of the general severity of scabbiness and russeting. The fruits were all examined by the junior writer alone.

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[24]This relation of fruit fall to spray is often reversed when scab is more abundant, as regards to spray and check plots. (Wallace, Errett. Scab disease of apples. New York Cornell Agr. Exp. Sta. Bul. 335. 1913. See p. 552-553.) See also p. 133, on experiments in 1919, plot 13. In regard to spray and dust, in Massachusetts "where the foliage was burned by the lime-sulphur, from 8 to 20 per cent of the fruit dropped prematurely; while where the sulphur dust was used, practically the entire crop remained on the trees." (Krout, Webster S. *Op. cit.*, p. 36.) The burning from lime-sulphur spray is attributed by Krout to the prevalence of high temperature and high humidity at the time of application rather than to drenching with the spray mixture. (*Ibid.*, p. 38.) For a different explanation by Sanders see text, p. 170, and footnote.[65] As early as in 1910, "dropping of fruit and leaves are noted in one experiment." (Parrott, P. J., and W. J. Schoene. Experiments with home-made concentrated lime-sulphur mixtures. New York Geneva Agr. Exp. Sta. Bul. 330. 1910. See p. 452.)

[25]The probable chief cause of fruit-drop here this year is indicated by considering the kind of labor available (p. 142) together with the statement: "The damage from lime sulphur is increased when it is directed against the underside of the leaf or when it is shot up out of a spray gun." (Sanders, G. E. Apple Spraying. 18th Ann. Rpt. Com'r. Agri. Maine. 1919, p. 207.)

TABLE 7.

Results from sorting fruits in 1924.

Plot[1]	Schedule	Number of apples			
		Total	Smooth[2]	Scabby[2]	Russeted[2]
			%	%	%
1-N	(1)(2)(3)(4)(5)[3] Commercial liquid lime-sulphur 1.25-50[4], with 1 pound dry lead arsenate added for (4) and (5)	2509	75	3	23
1-S	Ditto	2179	66	2	33
2-N	Unsprayed check	4870	47	49	6
2-S	Ditto	5232	54	31	18
3-N	(2)(3)(4)(5)(6) Commercial liquid lime-sulphur 1.25-50, with 1 pound dry lead arsenate added for (4) and (5)	1801	71	3	27
3-S	Ditto	1398	63	6	31
4-N	(2)(3)(4)(5)(6) Commercial liquid lime-sulphur 1.25-50, with 0.5 pound Kayso spreader each time, and with 1 pound dry lead arsenate added for (4) and (5)	1403	68	5	28
4-S	Ditto	1052	61	5	35
5-N	(2)(3)(4)(5)(6) Pomodust[5]	3892	83	3	15
5-S	Ditto	3716	74	5	21
6-N	(2)(3)(4)(5) Commercial liquid lime-sulphur 1.25-50, with 1 pound dry lead arsenate added for (4) and (5)	1965	71	2	27
6-S	Ditto	2314	60	3	37
7-N	(3)(4)(5)(6) Commercial liquid lime-sulphur 1.25-50, with 1 pound dry lead arsenate added for (4) and (5)	2400	62	2	36
7-S	Ditto	1666	60	3	37
S-D[6]	(1)(3) Lime-sulphur spray; (4)(5)(6) pomodust; (7) dusting sulphur	5188	70	12	19

[1]See Chart 3 for location of plots.

[2]The double counting of apples both scabby and russeted, and the non-inclusion of fractions of percentages, sometimes result in the percentages totaling more or less than 100.

[3]These numbers refer to (1) delayed dormant, (2) pre-pink, (3) pink, (4) calyx, (5) two-weeks, and (6) four-weeks applications. The times of the different applications and the conditions of the leaves or blossoms on different dates, are given on p. 143 of the text.

[4]The two figures refer respectively to gallons of lime-sulphur concentrate and to gallons of made-up water solution.

[5]Consists of 90 parts sulphur and 10 parts lead arsenate.

[6]Not in the same part of the orchard as the other plots. The times of the applications also were not exactly the same (see text p. 150).

In Table 7 are given the results for each plot, as to scabbiness and russeting, lumped as in preceding tables for previous years. These lumped results will be considered before an analysis is made of the data for individual trees. It is seen in Table 7 that the percentage of scab differed from 3 to 6 in the duplicate plots 3-N and 3-S, receiving five spray applications. This difference indicates that the smaller differences between the six series of sprayed and dusted plots are not significant. That is, conditions other than those of the planned procedure of spraying and dusting probably caused the variations in the sprayed and dusted plots. It will also be noted that the scab percentage differed from

31 to 49 per cent for the two unsprayed check plots. General notes were made as to the degree of scabbiness in each tree's yield of fruit.[26] It was common to find all degrees from pin-point spots and spots scarcely breaking the skin, to infection causing distortion and cracking. Furthermore no correlation appeared with the schedule followed, though apparently the severity of infection averaged somewhat greater on the check plots. Here again it seems that early infection was general, the first spraying being less thorough because of wind, and that the use of fungicides together with unusual dryness in June (see Table 11) checked further spread of the disease. A result was that the pre-pink application was without apparent value. This application is discussed more at length on p. 172. Another conclusion is that the use of a casein spreader was without value. This is discussed further on p. 182.

In Table 7 the percentage of russeting differed 10 per cent or more in several duplicate pairs of plots, including the checks, which is more than the difference between one sprayed pair and another. However, the sprayed plots all showed more than any dusted or check plot. The standard of russeting that was applied included in the record, as russeted, every fruit with about a square inch or more of surface not perfectly smooth. This included what is called "net-russeting," a characteristic that probably is involved more with the qualities of a fancy grade of fruit. The other more severe degrees of russeting were practically

[26]Ballou, F. H., and I. P. Lewis. Spraying experiments in southeastern Ohio. Ohio Agr. Exp. Sta. Mo. Bul. 99-100. 1924. See p. 40 for a definition of degrees of scabbiness as recorded in Ohio.

negligible this season. Russeting was reported for lime-sulphur on this farm as early as 1910.[27]

Included in Table 7 are the results of sorting most of the ffuit from five trees in another orchard on the same farm as the 14 plots. Here spray was applied on May 9 to 11, and on May 30, the pre-pink being omitted. Dust was applied on June 13, June 27, July 11, and August 15. The scab percentage was higher than for any of the sprayed or dusted plots. No certain explanation for this is known, inasmuch as no increase in scab accompanied the omission of both the first and second applications in plots 7-N and 7-S, or the use of dust in plots 5-N and 5-S. Possibly the use of dust in the last two plots was more liberal. Also, the effects of the omission of the pre-pink may have been corrected by the calyx spraying in plots 7-N and 7-S better than by the calyx dusting here. The five count trees were selected as being in different rows (as rows were sprayed or dusted), and as being high-yielding and as close together as possible considering their being in different rows.

The percentage of smooth fruits was least for the unsprayed checks, because of scab and in spite of less russeting. With scab about the same for the other plots, and with russeting varying as was previously described, the percentage of smooth fruits also varied without correlation with the planned spraying procedure, and with a slightly better showing by the dusted plots.[28]

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[27]Bonns, W. W. Orchard spraying problems and experiments: A review of, and a contribution to previous data. Maine Agr. Exp. Sta. Bul. 189. 1911. See p. 67.

The following also is of interest here, from Connecticut Agr. College Ext. Bul. 70, by W. H. Darrow. 1924. See p. 7: "In the southern sections of the State where more or less burning and russeting has sometimes resulted from the use of commercial lime sulphur in the summer sprays, Dry-Mix Sulphur Lime (12½ lbs.) or self-boiled lime sulphur (8-8-50 formula) or Atomic Sulphur (6 lbs. to 50 gals.) may be substituted for the commercial lime sulphur in sprays 4 to 8 inclusive [calyx and following.] This becomes important when dealing with varieties susceptible to russeting, such as Williams, Ben Davis and Grimes." In New Jersey, considering "Ben Davis a variety that is very susceptible to lime-sulphur injury," dry-mix sulphur lime is strongly recommended as a substitute for liquid lime-sulphur for use on varieties of apples that are easily russetted, beginning with the petal-fall (calyx) application. (Farley, Arthur J., Dry-mix sulfur lime. A substitute for self-boiled lime-sulfur and summer-strength concentrated lime-sulfur. New Jersey Agr. Exp. Sta. Bul. 379. 1923. See p. 15 and 16.)

[28]See p. 176 for a general discussion on dusting.

The seven plots in the north tier in the 1924 series were included in plots of the 1923 series. A comparison as to the scab percentage is made in Table 6. Apparently lack of control in 1923 had no effect in 1924 in creating a difference between plots, while lack of control measures in 1924 created a difference between plots that were alike in 1923. It may also be pointed out that scab was controlled well in plots adjacent to the check plots, in both 1923 and 1924.

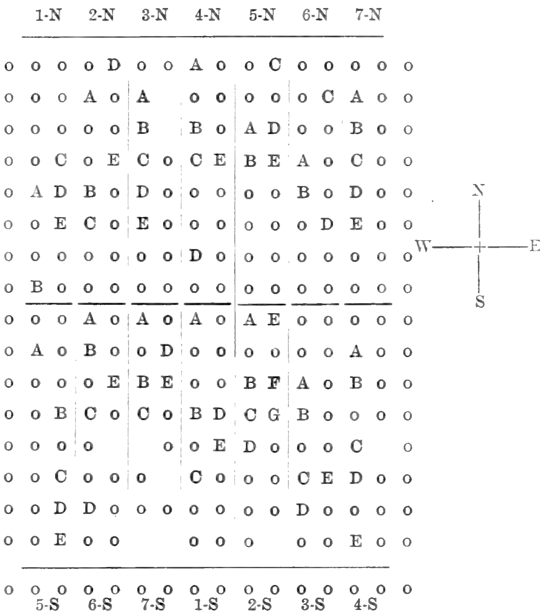

CHART 3. Arrangement of the plots in the 1924 series. Each letter represents a tree. The numerals refer to the schedules followed (see Table 7), and the capital letters indicate count trees.

DATA FROM INDIVIDUAL TREES.

The location of the count trees is given in Chart 3. The results lumped for each plot are given in Table 7. There it is shown that duplicate plots differed from each other as much as one sprayed plot differed from any other having a different spray schedule. The reason for such variation, and its significance in relation to the spray and dust schedules, may be shown by an analysis of the individual tree data.[29]

The count halves of the count trees were graded from 1 to 5 in the order of increasing abundance of leaves as seen on September 30. With great variation occurring among the trees in each plot, the resulting average for foliage abundance was markedly higher in the check plots, and somewhat higher in the dusted plots, than in the sprayed plots. There was some indication of greater reduction of foliage from the last (July 9) spray application than from the first or second, and of greater reduction with the spreader than without it.[30] The driving nature of the spray as applied is thought to have been at least one cause of burning,[25] with the preceding wet, cold spring weather and the lack of vigor of the trees also possibly serving as causes.[31]

The means, with their probable errors, for the yield, size, and sorted grades of fruit, are given in Table 8. It appears there that in yield the check and dusted plots surpassed the sprayed plots. This should not be emphasized too much, because a number of conditions influenced the results, but it is at least suggestive that the five count half-trees, chosen chiefly for apparent highest yield in each plot, should give the highest yield mean in the four plots not receiving spray. Furthermore, in a table comparing each plot with every other plot in regard to the difference between the means and the ratio of this difference to its probable error, the ratio was over 5:1 in 9 out of 20 comparisons between check and spray, and in 7 out of 20 comparisons between dust and spray, but in only 4 out of 40 comparisons between one spray treatment and another. This indicates that in general the yield rate was favored enough by lack of wet spray to overcome the effect of tree variation.

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[29]The reasons for making such an analysis are detailed by Donald Reddick and C. R. Crosby. (Further experiments in the dusting and spraying of apples. New York Cornell Agr. Exp. Sta. Bul. 354. 1915. See p. 68.) In general it is to furnish a measure of the reliability of the experimental results. In this bulletin the probable error is worked out by the usual method, as advised by the Biology Dept. of the Maine Station.

[30]See p. 182 for a general discussion on spreaders.

[31]Wallace, Errett. Spray injury induced by lime-sulphur preparations. New York Cornell Agr. Exp. Sta. Bul. 288. 1910. See p. 108, 116, 117, 125, and 127.

See also text, p. 170, and footnote[65].

TABLE 8.

Results in 1924, based on data on fruit from individual trees.[1]

Plot	Number of count trees	Yield	Fruits			
			Size[2]	Smooth	Scabby	Russeted
		Barrels		%	%	%
1-N	5	0.94±.12	18.2±0.9	76.4±2.3	2.4±0.5	21.6±2.2
1-S	5	0.88±.10	19.8±0.8	65.6±2.9	2.0±0.3	32.8±3.0
2-N	5	1.64±.11	16.6±0.3	46.6±2.0	48.6±2.1	6.0±0.7
2-S	7	1.04±.07	14.1±0.2	54.4±2.0	30.0±2.5	19.9±2.4
3-N	5	0.74±.07	20.8±0.3	69.2±4.6	2.6±0.4	28.4±4.6
3-S	5	0.50±.03	17.6±0.2	62.8±2.5	5.4±0.9	32.2±2.8
4-N	5	0.58±.09	20.6±0.6	66.2±4.0	4.6±0.3	29.8±4.0
4-S	5	0.32±.05	14.4±0.9	63.6±3.1	4.4±0.7	32.4±3.3
5-N	3[3]	1.24±.03	16.7±0.4	82.0±3.1	3.0±0.6	15.3±3.0
5-S	5	1.20±.09	16.4±0.3	72.6±2.2	5.4±0.6	22.8±2.8
6-N	4	1.00±.06	20.3±0.5	71.5±4.7	1.5±0.4	27.0±4.9
6-S	5	0.92±.06	19.8±0.5	59.2±1.8	3.0±0.4	38.0±1.7
7-N	5	0.92±.12	19.2±0.4	57.8±3.2	1.6±0.1	38.6±2.8
7-S	5	0.66±.06	20.0±1.0	58.4±4.0	3.2±0.2	39.0±4.0
S-D	5			70.4±1.4	12.4±1.1	18.2±2.5

[1]See Table 7 for lumped results from these plots.
[2]The size index is the result obtained by dividing the number of barrels of yield by the total number of apples, and by then considering .0001 as a unit in the index. An index of 20 indicates 500 apples to the barrel and an index of 16.7 indicates 600 apples to the barrel.
[3]Of the five trees included in Table 7, two had the fruit mixed in an accident occurring in transit from the orchard to the sorting shed.

The index for size of fruit given in Table 8 is the result obtained by dividing the number of barrels of yield by the total number of fruits as determined in the count, and then considering .0001 as a unit in the index. Thus 500 apples to the barrel would give 20 as a size index, while 600 would give 16.7 and 700 would give 14.3. The size index was smaller for the check and dusted plots (14.1 to 16.7) than for the sprayed plots (17.6 to 20.8) with the exception of plot 4-S (14.4.) A smaller average size of apples thus accompanied the larger yield in the unsprayed plots, but in plot 4-S the smaller size accompanied the lowest yield of any plot. The trees in this plot (in the south-east corner of the experimental area) properly belonged to the less thrifty part of the orchard that was not thought suitable for experimentation. In a table comparing the plots as to the means for size of apple, the ratio of the difference to its probable error was over 8:1 in 7 out of 20 comparisons between check and spray and in 2 out of 20 comparisons between dust and spray, but in no comparison between one spray treatment and another.

TABLE 9.

Comparison of percentages of scabby apples in Table 8, giving difference between means and probable error of difference;[1] also ratio between difference and its probable error.

(Plot below compared with plot to right)	1-N	1-S	2-N	2-S	3-N	3-S	4-N	4-S	5-N	5-S	6-N	6-S	7-N	7-S
1-N Difference:P.E.		.4±.6 (1:1.5)	46.2±2.2 (21.0:1)	28.6±2.5 (11.4:1)	.2±.6 (1:3.0)	3.0±1.0 (3.0:1)	2.2±.6 (3.7:1)	2.0±.7 (2.9:1)	.6±.8 (1:1.3)	3.0±.8 (3.8:1)	.9±.6 (1.5:1)	.6±.6 (1.0:1)	.8±.5 (1.6:1)	.8±.5 (1.6:1)
1-S Difference:P.E.			46.6±2.1 (22.2:1)	28.0±2.5 (11.2:1)	.6±.5 (1.2:1)	3.4±.9 (3.8:1)	2.6±.4 (6.5:1)	2.4±.8 (3.0:1)	1.0±.7 (1.4:1)	3.4±.7 (4.9:1)	.5±.5 (1.0:1)	1.0±.5 (2.0:1)	.4±.3 (1.3:1)	1.2±.4 (3.0:1)
2-N Difference:P.E.				18.6±3.3 (5.7:1)	46.0±2.1 (21.9:1)	43.2±2.3 (18.8:1)	44.0±2.1 (21.0:1)	44.2±2.2 (20.1:1)	45.6±2.2 (20.7:1)	43.2±2.2 (19.6:1)	47.1±2.1 (22.4:1)	45.6±2.1 (21.7:1)	47.0±2.1 (22.4:1)	45.4±2.1 (21.5:1)
2-S Difference:P.E.					27.4±2.5 (11.0:1)	24.6±2.7 (9.1:1)	25.4±2.5 (10.2:1)	25.6±2.6 (9.8:1)	27.0±2.6 (10.4:1)	24.6±2.6 (9.4:1)	28.5±2.5 (11.4:1)	27.0±2.5 (10.8:1)	28.4±2.5 (11.4:1)	26.8±2.5 (10.7:1)
3-N Difference:P.E.						2.8±1.0 (2.8:1)	2.0±.5 (4.0:1)	1.8±.8 (2.3:1)	.4±.7 (1:1.7)	2.8±.7 (4.0:1)	1.1±.6 (1.8:1)	.4±.6 (1:1.5)	1.0±.4 (2.5:1)	.6±.4 (1.5:1)
3-S Difference:P.E.							.8±.9 (1:1.1)	1.0±1.1 (1:1.1)	2.4±1.1 (2.2:1)	.0±1.1	3.9±1.0 (3.9:1)	2.4±1.0 (2.4:1)	3.8±.9 (4.2:1)	2.2±.9 (2.4:1)
4-N Difference:P.E.								.2±.8 (1:4.0)	.4±.7 (1:1.8)	.8±.7 (1.1:1)	3.1±.5 (6.2:1)	1.6±.5 (3.2:1)	3.0±.3 (10.0:1)	1.4±.4 (3.5:1)
4-S Difference:P.E.									1.4±.9 (1.6:1)	1.0±.9 (1.1:1)	2.9±.8 (3.6:1)	1.4±.8 (1.8:1)	2.8±.7 (4.0:1)	1.2±.7 (1.7:1)
5-N Difference:P.E.										2.4±.8 (3.0:1)	1.5±.7 (2.1:1)	.0±.7	1.4±.6 (2.3:1)	.2±.6 (1:3.0)
5-S Difference:P.E.											3.9±.7 (5.6:1)	2.4±.7 (3.4:1)	3.8±.6 (6.3:1)	2.2±.6 (3.7:1)
6-N Difference:P.E.												1.5±.6 (2.5:1)	.1±.4 (1:4.0)	1.7±.4 (4.3:1)
6-S Difference:P.E.													1.4±.4 (3.5:1)	.2±.4 (1:2.0)
7-N Difference:P.E.														1.6±.2 (8.0:1)
S-D Difference:P.E.	10.0±1.2 (8.3:1)	10.4±1.1 (9.5:1)	36.2±2.4 (15.1:1)	17.6±2.7 (6.5:1)	9.8±1.2 (8.2:1)	7:0±1.4 (5.0:1)	7.8±1.1 (7.1:1)	8.0±1.3 (6.2:1)	9.4±1.3 (7.2:1)	7.0±1.3 (5.4:1)	10.9±1.2 (9.1:1)	9.4±1.2 (7.8:1)	10.8±1.1 (9.8:1)	9.2±1.1 (8.4:1)

[1]Calculated as the square root of the sums of the squares of the probable errors of the means.

Therefore the fruit-fall observed after spraying (p. 146) did not cause a correspondingly great decrease in yield because the fruits grew larger, compensating somewhat for their being fewer. Just how much in commercial aspects the smaller size of fruit in the check and dusted plots counter balanced the greater yield in these plots, could not be determined with the facilities that were available. The final test, of course, is the net profit, which depends somewhat on the grade. If the smaller size in the checks did not reduce profits, then yield reduction by spraying did tend to reduce profits. This may not happen often, may be the result of unskillful use of spray guns, and is not a good reason for letting scab go uncontrolled, but it is something to consider in comparing and testing new and different fungicides, or methods of applying fungicides.

The means for scab percentage given in Table 8 are compared in Table 9. The ratio of the difference to its probable error is 8.0:1 in the comparison of duplicate plots 7-N and 7-S. A ratio of over 8:1 does not appear in the comparison between the two check plots, appears in every comparison between check and dust, or between check and spray, appears in only one comparison between one spray treatment and another, and does not appear in any comparison between dust and spray. In other words, the absence of dust or spray overshadowed tree variation in the effects on scab percentage; but tree variation practically always was of greater effect than differences in planned procedure with dust or spray, so that one dust or spray schedule was not significantly better than another. In an attempt to correlate color and location of the fruit on the count half-tree with scab percentage, it was found among the check trees, where scab percentage ran as extremely as from 19 to 52 per cent in three consecutive trees, that there was no apparent effect from degree of color, but that there was more scab with an even distribution of the fruit over the tree than with a greater proportion on the lower branches. Among the dusted and sprayed trees, with the scab percentage as great as 2 and 11 for two adjacent sprayed trees, there was both more color (red) and somewhat more scab in the half-trees facing the West, and as then might be expected, there was more scab with more color. These differences were not great, however. No explanation can be offered for the variation among check trees. The two extra ones selected in plot 2-S (see p. 147) showed 28 and 30 per cent scab, about like the plot mean. Among the others, smaller differences were secured than were expected in view of the apparent difficulties encountered in making several of the applications of spray or dust.

It is shown in Table 9 that the combination spray-dust plot differed in scab percentage from one check plot more significantly than from the others, though the difference was quite significant in all comparisons. This indicates some control, but it was significantly worse than that obtained in the other part of the orchard.

Except for Plot 1-N, the four check and dusted plots had the lowest means for the percentage of fruit-russeting. In a table comparing the plots as to these means, the ratio of the difference to its probable error was over 3:1 in 15 out of 20 comparisons between check and spray, in 9 out of 20 comparisons between dust and spray, and in only 3 out of 40 comparisons between one spray treatment and another. The same was true also in 6 out of 8 comparisons between the spray-dust combination and spray, but not in the 2 comparisons between this combination and dust. Such a ratio appeared in the comparison of the two check plots, but not in the comparison of any other duplicate plots. Although spray as against dust or no treatment overshadowed tree variation in the effects on fruit-russeting, tree variation practically always was of greater effect than differences in planned procedure with spray. In an attempt to correlate color and location of the fruit on the count half-tree with the percentage of russeting, it was found among the check trees, where the percentage ran as extremely as from 13 to 37 per cent in three consecutive trees, and among dusted trees, with the percentage as different as 11 and 30 per cent for two adjacent trees, that there was more russeting with a greater proportion of the fruit on the lower branches, and with the count half-trees facing the east, but not with a difference in degree of color. Among the sprayed trees there was more russeting with more even distribution of fruit, and with less degree of color.

The percentage of smooth fruits depended upon the percentage of scabby and russeted fruits, and was lowest for the check plots and highest for the two dusted plots and the sprayed plot 1-N. In comparisons between plots, the ratio of the difference to its probable error was more than 3:1 in 15 out of 24 comparisons between check and dust or spray, in 8 out of 20 comparisons between dust and spray, and in only 4 out of 40 comparisons between one spray treatment and another, these 4 being concerned with the plot 1-N named above as having the least russeting. The combination spray-dust plot differed from the checks more significantly than from the dust and spray plots.

There were practically no windfalls until the day before the fruit was picked when a heavy wind produced some. Some insects were present (aphids, canker worm, codling moth, curculio, maggot or railroad worm, oyster shell scale, and tent caterpillar) but their combined effects even in the unsprayed plots were negligible.

DISCUSSION AND GENERAL CONCLUSIONS

Apple growers of course are not, or at least are not expected to be, interested in experiments for the sake of the experiments, but rather for the sake of any suggested practices that will yield greater profit than their present practices do. A grower wants to know whether scab can be controlled in his orchard; if not, why not; if so, how and with what profit.[32] Sometimes new methods and materials when tested in order to improve upon those in use, prove inferior or injurious. This may seem to waste the energy of the experimenter, but should serve to save some trouble for those growers who would otherwise be inclined to try new methods themselves. Even a generally effective standard control method might prove unprofitable in some places because of natural conditions that are unfavorable to frequent severe losses from diseases. It seems well to take stock briefly here as to the practical suggestions offered by the series of apple scab spraying experiments begun on Highmoor Farm in 1910 and carried on almost continuously since then.

These experiments have been conducted in what is essentially one large orchard (Highmoor Farm Orchards No. 1 and No. 2, separated by a road) of one variety (Ben Davis). One advantage resulting from this is that a number of different methods or materials could be compared during the same season under somewhat similar conditions. The relative merits of methods or materials appearing in such a comparison are more certain than

[32]In New York in 1905, of 108 reports 10 claimed "that spraying had done more damage than the apple scab for which it was used," referring to spraying with Bordeaux mixture. (Hedrick, U. P. *Op. cit.*, p. 112.)

when methods or materials are used in different orchards and the results compared. Even on Highmoor Farm, sometimes dissimilar results have arisen from the same treatment in different parts of the same orchard, as, for example, the difference between 31 and 49 per cent scab in two check plots in 1924, not to mention the individual tree differences in many respects.[33] Another advantage is that from the use of the same method through many seasons in the same orchard, more reliable conclusions can be drawn as to the effect of seasonal variations. Of course the increase in the age of the trees progressively changes conditions somewhat with passing seasons, but the trees were already from 20 to 25 years old when this series of experiments was begun and apparently presented about the same problem then as they have since.

However, there are also certain disadvantages that result from confining experimental work to one orchard. The strict applicability to other orchards of scab control methods that prove desirable at Highmoor Farm is somewhat in doubt because of differences in variety, slope and soil, methods of care, kind of weather at important times, the standards and experience of the persons making the applications, and the abundance of overwintering scab. The same efforts elsewhere may give better or worse results.[34]

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[33]True also in Nebraska. "One of the greatest difficulties lay in the individual variation of trees. Another difficulty was the very noticeable variation in amount of disease infection and insect infestation in various parts of the same orchard. (J. Ralph Cooper. *Op. cit.,* p. 7.)

[34]In Nebraska "scab was always found to be more prevalent where no cultivation was practiced and decidedly less in evidence where thoro, early and late cultivation was practiced.

"Well pruned and spaced trees were as a rule less scabby than trees which carried a dense foliage or which were so close together that the branches interlocked. This should be expected, since the more dense the foliage the longer the tree will remain moist and afford the best conditions for the germination of spores.

"It was noticed that trees situated on high, rolling land were usually not so badly infected as trees on lower ground. This is due in part to the better circulation of air on the rolling land and in part to the dense foliage found on trees growing in low places, especially where proper pruning is not given." (*Ibid.,* p. 50.)

A summary of opinions got early in the history of spraying, in 1892, from several regions gives Ben Davis a place among the less susceptible varieties in the absence of control measures. (Lodeman, E. G. Spraying apple orchards in a wet season. New York Cornell Agr. Exp. Sta. Bul. 48. 1892. See p. 380.) However, "either the strain of Ben Davis set at Highmoor is extremely susceptible to scab, or else local conditions are particularly favorable for the development of the scab fungus." (18th Ann. Rpt. Com'r. Agri. Maine. 1919. p. 197.) Also, Reddick and Crosby (*op. cit.,* p. 71) consider the Ben Davis a variety particularly susceptible to scab, and in West Virginia Ben Davis are among the more susceptible varieties (Peairs, L. M., and E. C. Sherwood. Orchard Spraying. West Virginia Agr. Exp. Sta. Circ. 36. 1924. See p. 5.)

TABLE 10.

Comparison of spraying, flower development, and scabbiness on experimental plots at Highmoor Farm, 1910 to 1924 inclusive.[1]

Year	Time of applications				Time of appearance of scab (T.A.S.)	Interval P - T.A.S.	Percentage of fruits scabby			
	First[2]	Pink (P)	Calyx (C)	Interval P - C			Unsprayed	Bordeaux[3]	Lime-Sulphur[3]	Dust[3]
				Days		Days	%	%	%	%
1910	—	May 13-16	June 7-9	22	—	—	41-42	14-17	7-15	—
1911	—	May 12-13	May 30	17	—	—	0	0	0	—
1912	—	May 24	June 5	12	June 5-July 1	12-38	81	—	1	—
1913	—	May 8	June 3	26	June 10	34	39	1	1-3	—
1914	—	May 23-25	June 6	12	June 23-30	29-36	13	Trace[8]	1-2	—
1915	May 8[13]	May 14	June 3	20	July 28	75	5	Trace	Trace	—
1916	—	May 20	June 5	16	June 26	37	39	Trace	1-2	—
1917	—	May 30	June 20	21	June 20-July 9	21-40	98	—	45-68	—
1918	—	May 19-20	June 4	15	June 4-13	15-24	83	—	2-22	—
1919	—	May 19-20	June 6	17	May 28-June 5	8-16	98	26[9]	33	—
1920	—	—	—	—	—	—	—	—	—	—
1921	—	May 6	May 24	18	—	—	25	—	5	25
1922	May 12	May 17	May 22	5	—	—	76	—	17[4]-68	38-46[5]
1923	May 19	May 24	June 7	14	—	—	58	—	1-9[6]	19-25[7]
1924	May 10	May 30	June 13	14	June 11	12	40	—	3[14]	4[15]
Mean	—	May 19[10]	June 4[11]	16	—	—	50[12]	—	8[12]	—

[1]In part compiled from Maine Agr. Exp. Sta. Bul. 189, 198, 212, 223, 240, 252 and 271.
[2]Unless otherwise indicated, the pink application was the first.
[3]Applied three times, in combination with lead arsenate, unless stated otherwise.
[4]With four applications.
[5]All dusted plots had four applications.
[6]With five applications in all plots, but not all on same date; none with more than one application before the pink.
[7]With five applications, but not at same times as for any spray plot.
[8]"Trace" denotes less than one-half of one per cent.
[9]With less copper than in preceding years.
[10]Last date given for each year considered in determining the mean.
[11]First date given for each year considered in determining the mean.
[12]Minimum given for each year considered in determining the mean.
[13]Delayed dormant application.
[14]With four and five applications.
[15]With five applications.

A practical interpretation of the results of spraying Ben Davis on Highmoor Farm will first be presented, followed by a comparison with results from spraying in other states, by a discussion of the pre-pink application, of dusting, and of casein spreaders, and finally by suggestions for the application of principles of scab control by apple growers.

CONCLUSIONS AS TO PROFITS FROM SPRAYING BEN DAVIS ON HIGHMOOR FARM.

As is shown in Table 10, from 1911 to 1916, inclusive, scab was controlled well on Highmoor Farm by only three applications of lime-sulphur beginning with the pink, this schedule always allowing less than 5 per cent scab to develop although in four seasons the scab percentage was 13 or more on the check plots. Then the same schedule was not effective in 1917, 1918, and 1919.[35] A comparison of the weather records taken at Highmoor Farm for these three years and for 1916 and 1921, two years in which a standard three-application schedule controlled scab, shows (Table 11) that the difference was not determined solely by total precipitation in the five-month period beginning May 1, inasmuch as 1916 was not drier than the next three years according to the total precipitation index. However, 1919 was markedly wetter and 1921 decidedly drier than the other seasons, giving a probable explanation for high scab percentages in the former year and for low scab percentages in the latter year. In 1916, control may have been made easy by rather less rainfall than usual in July, August, and September. In 1917 the first application was made six days later than in any of the preceding seven years, the lateness being due to "unseasonably cold, wet weather,"[36] and the second application was made almost two weeks later than the latest date for the preceding seven years. (See Table 10.) There was also a rather wet June and August. These conditions probably favored high scab percentages. In 1919, scab appeared earlier than usual, and there was a rather

[35]It is also reported that in Virginia scab has become worse since 1917. (Schneiderhan, F. J., and F. D. Fromme. Apple scab and its control in Virginia. Virginia Agr. Expt. Sta. Bul. 236. 1924. See p. 3.)

[36]Morse, W. J. Apple spraying experiments in 1916 and 1917. Maine Agr. Exp. Sta. Bul. 271. 1918. See p. 112.

TABLE 11.

Transcript from records of rainfall at selected stations in apple-growing regions.

Station	Year	Rainfall in inches					Total
		May	June	July	August	September	
Highmoor Farm[1]	1916	5.77	4.20	2.25	2.96	3.09	18.27
Ditto	1917	2.08	7.47	2.65	4.89	1.83	18.92
Ditto	1918	2.52	4.80	6.74	6.00	8.86	28.92
Ditto	1919	5.08	1.09	2.68	2.89	5.72	17.46
Ditto	1921	1.19	1.79	2.18	3.51	1.05	9.72
Lewiston, Me.	1921[3]	1.87	2.47	1.68	2.38	2.33	10.73
Ditto	1922[5]	5.69	8.71	3.33	3.00	2.01	22.74
Ditto	1923[5]	2.01	2.43	4.12	0.98	3.07	12.61
Ditto	1924[5]	6.12	1.21	2.59	5.25	5.81	20.98
Highmoor Farm and Lewiston	Mean normal for 1916-19 at H. F. and 1921-24 at Lewiston	3.89	4.05	3.26	3.54	4.09	18.83
Annapolis Royal, N.S.	Mean normal for 1916-1919 and 1921-24[4]	2.04	2.90	3.74	3.63	3.35	15.66
Lewiston, Me.	Mean normal[2]	3.5	3.6	3.6	3.4	3.4	17.5
Fitchburg, Mass.	Mean normal[2]	3.6	3.0	2.9	4.4	3.4	17.3
Rochester, N. Y.	Mean normal[2]	3.0	3.1	3.1	2.9	2.3	14.4
Martinsburg, W. Va.	Mean normal[2]	4.2	3.6	3.7	3.2	2.5	17.2
Griggsville, Ill.	Mean normal[2]	5.3	4.5	3.7	2.7	4.0	20.2
Greenville, Me.	Mean normal[6]	3.47	3.69	4.24	3.80	4.17	19.37
Boston, Mass.	Mean normal[6]	3.51	3.03	3.36	4.03	3.19	17.12
Buffalo, N. Y.	Mean normal[6]	3.10	3.14	3.40	2.99	3.18	15.81
Pittsburgh, Pa.	Mean normal[6]	3.30	3.89	4.42	3.18	2.48	17.27
Lynchburg, Va.	Mean normal[6]	3.99	3.89	4.03	4.25	3.63	19.79
Parkersburg, W. Va.	Mean normal[6]	3.46	4.65	4.66	3.53	2.72	19.02
Cincinnati, O.	Mean normal[6]	3.52	3.98	3.54	3.33	2.31	16.68
Grand Rapids, Mich.	Mean normal[6]	3.34	2.52	2.63	2.59	3.12	14.20
Madison, Wisc.	Mean normal[6]	3.62	4.10	3.99	3.21	3.18	18.10
Peoria, Ill.	Mean normal[6]	4.26	4.30	2.97	2.93	3.12	17.58
Omaha, Nebr.	Mean normal[6]	4.50	5.05	4.33	3.62	3.03	20.53
Portland, Oreg.	Mean normal[6]	2.36	1.78	0.54	0.65	1.84	7.17

[1]Situated near Lewiston, Me.
[2]Data from Henry, Alfred Judson. Climatology of the United States. U. S. Dept. Agri. Weather Bur. Bul. Q. 1906. See p. 130, 151, 184, 746, and 689.
[3]Data from the Report of the Chief of the Weather Bureau 1921-1922. U. S. Dept. Agri. 1923. See p. 215.
[4]Data in script from the Entomological Laboratory, Annapolis Royal, N. S.
[5]Data in script from the Weather Bureau, Boston, Mass.
[6]Based on records of 20 or more years of observations. Data from Agricultural Yearbook 1923. U. S. Dept. Agri. Table 737.

wet May and September. Thus there are good reasons why the three-application schedule failed in 1917 and 1919. The question here that is of the most interest to the apple grower is whether a schedule of only three applications will fail often enough to make a fourth application (earlier or later, depending upon the type of season) profitable. This was answered in a way by the next season's results. Lime-sulphur was not effective in 1922 with four applications or in 1923 with five applications, in some plots. In 1922 the precipitation for May and June was unusually high (Table 10). That for July, 1923, was somewhat high. In 1924, four applications beginning with the pink gave control, with dryness of the mid-summer months helping. It seems that at least four applications should be made to be reasonably sure of scab control.

Table 10 also shows that, in spite of disappointing results in several years, spraying with lime-sulphur at Highmoor Farm on Ben Davis apples reduced the average scab percentage for 14 years from 50 per cent to 8 per cent. In brief, scab on this farm can usually or generally be controlled by three or four applications of lime-sulphur beginning with the pink, but not always. It is not known certainly why control failed in some seasons with this method, though some probable causes have been suggested. It also is not known what the costs of spraying were and what the profits were. The following question as to profit can be considered, however: On the basis of the past experience, recorded in Table 10, what are the chances for profit from spraying with lime-sulphur this next season? A number of assumptions and estimates are made and figures obtained, as follows.

Unit considered, 100 trees.
Number of applications, 4 per season.[37]
Amount applied per tree, 16 gallons per season.
Total applied to 100 trees, 1,600 gallons.
Total dry lime-sulphur at 4-50, 128 lbs.

[37]Four applications are more than were usually made and may at first thought seem to be too many as a standard. However, in one year (1923) more than four were necessary for the best control, and in several years the control in some plots receiving three applications was not as good as the control in the best plots which were used to get the average (8 per cent) in Table 10.

At 10 cents a lb.[38] $12.80

Total dry lead arsenate at 1-50 applied at calyx and two-weeks, 20 lbs.[39]

At 21½ cents a lb.[38] $4.30

Team and teamster for 1½ days at $3.00 for each per day 9.00

Two laborers for 1½ days at $3.00 for each per day 9.00

Original cost of 200-gallon sprayer, $500.

Interest on sprayer at 5 per cent, for 100 trees (1/10 of total number cared for) 2.50

Life of sprayer in numbers of individual tree-sprayings, 80,000

Depreciation per spraying of 100 trees four times 2.50

Annual repair of sprayer for 4,000 individual tree sprayings, $20.00

Repair per 100 trees one season 2.00

Gasoline and oil per 400 individual tree sprayings 0.20

Total cost of spraying 100 trees for one season 42.30

Average yield per 100 trees, 100 barrels

Cost, after grading, of handling and marketing 100 barrels of apples of which 8 per cent are scabby 147.20

Includes 8 bbls. at $0.00 (discarded)[40]

92 bbls. at $1.60, or $147.20

Gross receipts for preceding 276.00

Includes 8 bbls. at $0.00[40]

92 bbls. at $3.00, or $276.00

Cost, after grading, of handling and marketing 100 barrels of apples of which half are scabby 80.00

Includes 50 bbls. at $0.00 (discarded)[40]

50 bbls. at $1.60, or $80.00

Gross receipts for preceding 150.00

Includes 50 bbls. at $0.00[40]

50 bbls. at $3.00, or $150.00

Net receipts for 100 bbls. with 8% scab 128.80

Net receipts for 100 bbls. with 50% scab 70.00

Net receipts extra for spraying 100 trees four times 58.80

Extra cost of spraying 100 trees 42.30

Gain from spraying 100 trees 16.50

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[38]Including freight charges.

[39]Five gallons per tree used at these two applications, or 1,000 gallons in all. Lead arsenate costs are included because in comparing plots the fungicidal value appears to be greater here than the insecticidal value. An insecticide was omitted on the check plots in 1924 with no appreciable effect on insect infestation. In a commercial orchard not broken into plots the insecticidal value would have to be considered separately.

[40]The labor of discarding is considered as being about equivalent to the value for cider.

Thus in this Ben Davis orchard under the conditions of production, cost, and sale price given, the gain from spraying with the average maximum control received in the past will be fairly profitable if four applications of dry lime-sulphur are given. In any other orchard, even in Maine, many or all the items listed above probably would be different. In some susceptible varieties with a greater difference in net receipts between clean and scabby fruit, the profit from spraying would be greater. The figures given above are thought to be conservative as to possible profits from spraying. In any case, the problem of profits from spraying can best be studied and solved, by the individual apple grow-

TABLE 12.

Comparison of liquid lime-sulphur, dry lime-sulphur, and "modified" schedule with lime-sulphur followed by lead arsenate alone.[1]

Year	Liquid lime-sulphur[2]		Dry lime-sulphur[2]		"Modified" schedule[3]		Check	
	Plot No.	Scab	Plot No.	Scab	Plot No.	Scab	Plot No.	Scab
		%		%		%		%
1914	4	1.5			3	2.0	12	13
	10	0.7						
	Ave.	1.1						
1915	1	0.13			3	0.27	9	5
1916	1	0.7	8	1.3	5	1.6	9	39
	2	1.9						
	Ave.	1.3						
1917	5	68	10	56	3	57	9	98
	6	48						
	7	45						
	Ave.	54						
1918	3	19			11	12	8	83
	5	21						
	7	22						
	12[4]	2						
	Ave.	16						
1919	1	33			5	60	13	98
1922[5]	7	19	8	17			4	76
1923[6]	2	9	1	6			3	58
	6	5	5	7				
	10	1	7	3				
	Ave.	5	Ave.	5				

[1]In part compiled from Maine Agr. Exp. Sta. Bul. 240, 252, and 271.

[2]Applied three times, in combination with lead arsenate, unless otherwise stated; at 3 to 4 pounds in 50 gallons.

[3]First (pink) application lime-sulphur 20 per cent stronger than standard, plus one pound dry lead arsenate to 50 gallons. Second (calyx) and third applications two pounds dry lead arsenate to 50 gallons.

[4]Commercial liquid lime-sulphur concentrate used instead of home-made as was used elsewhere in this and previous years.

[5]Lime-sulphur applied four times in combination with lead arsenate, except in check plots.

[6]Lime-sulphur applied five times with lead arsenate used twice, except in check plots.

er, on the basis of somewhat similar records extending over at least ten years. It is of course well understood that profits from spraying are modified by the balanced consideration given to such fundamental practices as cultivation, fertilization, and pruning.

From the results on Highmoor Farm, alone, it would seem that lime-sulphur is the best general means for controlling apple scab to be recommended at present. This refers to the dry form as well as the liquid, as they were equally effective in tests made in 1916, 1917, 1922 and 1923 (Table 12).

In tests in Illinois in 1922, "dry lime sulphur appears to be inferior to the liquid form as a fungicide, but it is considered worthy of further tests on account of its favorable effects on fruit and foliage."[41] In Iowa in 1920, both dry and liquid lime-sulphur "reduced scab materially," on Northwestern Greenings and Ben Davis.[42] In Massachusetts, "liquid lime-sulfur 1-50 and dry lime-sulfur 4-50 proved of equal fungicidal efficiency for scab control. Less than 4 pounds of dry lime-sulfur in 50 gallons did not on the whole control scab quite as well as dry lime-sulfur 4-50."[43] Inferior results from the dry material have been reported from Michigan.[44] In Missouri, dry lime-sulphur at 2-50 or 3-50 will not give as good control as the liquid at 1.5-50, while 5-50 dry will.[45] In Ohio, 5-50 and 4-50 dry was practically as good as liquid 1.5-40.[46] In Pennsylvania, 3-50 dry lime-sulphur gave nearly as good control of scab as the liquid, and gave less foliage burning and fruit russeting.[47] In Wisconsin "in most tests the results from dry lime-sulphur 4-50 were similar to that obtained with liquid lime-sulphur 1-40."[48] In Ontario in 1922,

[41]Newton, F. W. Results of field experiments in spraying for 1922. Illinois State Hort. Soc. Trans. n. ser. 56 (1922) p. 128-139. As abstracted in Exp. Sta. Rec. 51:547.

[42]Herrick, R. S. The 1920 results of spraying in the apple grove orchard, Mitchellville, Iowa. Iowa State Hort. Soc. Rpt. 55:244-248. 1920 (1921). As abstracted in Bot. Abst. 11:273. Entry 1799.

[43]Doran, William L., and A. Vincent Osmun. *Op. cit.*, p. 12.

[44]Dutton, W. C., and Stanley Johnston. Dusting and spraying experiments of 1920 and 1921. Michigan Agr. Exp. Sta. Special Bul. 115. 1922. See p. 53.

[45]Swartwout, H. G. Spraying fruits for insect and fungus diseases. Missouri Agr. Exp. Sta. Bul. 210 (Rpt. for 1922-1923.) See p. 56-57.

[46]Ballou, F. H., and I. P. Lewis. *Op. cit.*, p. 38, 41-42.

[47]Thurston, H. W., Jr., R. C. Walton, and F. N. Fagan. Comparison of materials used in spraying and dusting for apple scab control in Pennsylvania. Pennsylvania Agr. Exp. Sta. Bul. 190. 1924. See p. 19.

[48]Wisconsin Agr. Exp. Sta. Bul. 352. 1923. Ann. Rpt. 1921-22. See p. 59.

the dry form controlled scab early in the season but not so well late in the season as the liquid.[49]

Table 12 also shows that in the years when the schedule was such as to permit lime-sulphur to control scab (1914, 1915, and 1916) practically as good control was got with the "modified" schedule. That is, with lime-sulphur 20 per cent stronger than standard (that is, 1.5-50 instead of 1.25-50) plus one pound dry lead arsenate to 50 gallons, for the first (pink) application and with a 2-50 lead arsenate spray for the second (calyx) and third applications. As good control was also got with this "modified" schedule as with lime-sulphur in two of the three years (1917, 1918, and 1919) in which scab was abundant on the check plots and was not controlled satisfactorily by lime-sulphur. Poorer control in 1919 may be due to weaker fungicidal power together with an unsatisfactory schedule.

The work done in other regions on standard materials tested at Highmoor Farm will be discussed in the following pages. A large number of still other spray materials have been tested in this and other regions, more especially elsewhere, that are not mentioned in this bulletin. Time is not available to digest and discuss the various reports concerned with these materials. Even if it were, they could not be recommended without being first tested here. The possibility of such testing will be referred to later. It is probable that lime-sulphur will eventually be superseded.[50]

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[49]Caesar, L. Some notes on spray matters. 15th Ann. Rpt. Quebec Soc. Prot. Plants. 1922-23. Quebec. See p. 31.

[50]"It is now thirteen years since Cordley first used lime-sulphur solution for the control of apple scab. Although lime-sulphur solution has since then practically displaced Bordeaux mixture for summer use in the apple orchard, a study of the literature on field experiments leads one to the conclusion that it is the toxicity of the latter to the host, rather than the great fungicidal merit of lime-sulphur which gradually brought about the change of practice. The prevailing opinion seems to be that as a fungicide for the control of apple scab lime-sulphur solution is not all that it ought to be. There has also been increasing dissatisfaction with lime-sulphur solution not only upon the ground that it could not be depended upon to control apple scab but also on account of injury to the host. In New Hampshire, lime-sulphur solution cannot be depended upon to control apple scab. A scab-free crop of McIntosh Red apple is not common even in thoroughly sprayed orchards in seasons when scab is general." (Doran, William L., Laboratory studies of the toxicity of some sulphur fungicides. New Hampshire Agr. Exp. Sta. Tech. Bul. 19. 1922. See p. 3.)

The cost and profits of spraying are discussed by Anderson and Roth.[51] Reports referred to by them are, however, based mostly on the use of the rod and small disk nozzles, dusting and the spray gun not being considered. Eventually a study of the problem of profits from different spraying and dusting methods in Maine will have to include tests in various representative orchards, commercial grading, the use of the different recommended standard varieties,[52] and cooperation in spraying small orchards.

GENERAL VALUE OF CONCLUSIONS FROM TESTS MADE IN OTHER REGIONS.

The apple scab problem and its study in Maine are involved with the more extensive problem and study of apple scab in the United States and Canada. In the study of the latter, hundreds of publications have been issued.[53] In spite of so much effort, the problem has proved to be sufficiently complicated with climatic and varietal factors, and with the discovery and development of new methods of research and control, so that a definite and complete solution has not been reached. In some states the apple disease problem has had much more time devoted to it than in Maine.[54] To a large extent this justifies the policy in Maine of merely testing the most promising methods developed in other

[51]Anderson, O. G., and F. C. Roth. Insecticides and fungicides. Spraying and dusting equipment. New York. 1923. See p. 171-174, 294, 301-304.

[52]The varieties urged by A. K. Gardner, Maine Extension Farm Crops Specialist, for the most general use in Maine are Wealthy, McIntosh, Red Delicious, Northern Spy, Baldwin, Rhode Island Greening, Gravenstein, and Wolf River.

[53]As early as in 1901, Clinton gave a list of 172 references (George P. Clinton. Apple scab. Illinois Agr. Exp. Sta. Bul. 67. 1901) and in 1914 Morris gave a list of 505 references (H. E. Morris. A contribution to our knowledge of apple scab. Montana Agr. Exp. Sta. Bul. 96. 1914.)

[54]In 1920, Maine ranked 18th in number of apple trees of bearing age and 8th in their acreage, among the states. (Gould, H. P. Apple growing east of the Mississippi River. U. S. Dept. Agri. Farmers' Bul. 1360. 1924. See Table 1 and Fig. 1.) This was correlated with 2.4 per cent of the number of trees of the country being in Maine. About 2 per cent of the country's crop is produced in Maine, according to data from the last thirty reports of the State Department of Agriculture and the 1923 yearbook of the U. S. Department of Agriculture.

states. Such a modest policy is even necessitated by the limitations in facilities and personnel here, together with the predominance of the potato in Maine as an agricultural product and as a source of disease problems.

The question may arise here even as to the necessity and desirability of devoting research in Maine to a problem that has received so much attention elsewhere. The reason for carrying on such research here lies in the location of the state, cutting the northern edge of the apple-growing belt at a corner[55] and consequently presenting a climate not strictly like that of other regions. The southern part of Maine, the part of the state where apples are grown, is somewhat different in regard to temperature, amount of precipitation, distribution of precipitation, or length of growing season, from most other apple growing regions.[56] Dissimilarity in regard to one or more of these environmental factors often appears to influence apple scab even in one region,[57] so that reasonable doubt is justified as to the strict applicability in Maine of methods developed elsewhere. A few examples will illustrate.

As is shown in Table 10, in 14 years in unsprayed Ben Davis plots on Highmoor Farm on the average 50 per cent of the fruits were scabby. As against this percentage of scab, which is the most serious trouble on apple here, it is stated that "it is a rare season in Illinois when unsprayed apples are marketable, except for cider and evaporating purposes."[58] In Michigan in some sea-

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[55]Gould, H. P. *Op. cit.,* Fig. 1.

[56]*Ibid.*

Reed, William Gardner. Atlas of American Agriculture. Part II. Climate. Section I. Frost and the growing season. U. S. Dept. Agri. Office of Farm Management. Advance Sheets, 2. Issued July 15, 1918. See Fig. 29.

Kincer, J. B. Atlas of American Agriculture. Part II. Climate. Section A. Precipitation and humidity. U. S. Dept. Agri. Office of Farm Management. Advance Sheets, No. 5. Issued March 15, 1922. See Fig. 15.

See tables 11 and 13.

[57]In adjoining counties of Delaware, ascospores in the same season have matured and discharged about three weeks earlier in one county than in another. This earlier discharge, and accompanying greater rainfall, have together made scab much more serious in the former county. (Adams, J. F. Cull apples and our orchard problems.) Trans. Peninsula Hort. Soc. 1924. Delaware State Bd. Agri. Bul. Vol. 13, No. 3:55-58. See p. 56.

[58]Pickett, B. S., *et. al.* Field experiments in spraying apple orchards in 1913 and 1914. Illinois Agr. Exp. Sta. Bul. 206. 1918. See p. 429.

sons "great quantities of apples were lost soon after packing and in storage and even during shipment through the agency of soft rots following apple scab. In some cases reported apples affected with scab began rotting while still attached to the trees, the loss in some cases amounting to four-fifths of the entire crop."[59] Again, in the same state four applications of 1.25-2.5-50 combination lime-sulphur (liquid) lead-arsenate (paste) spray in 1915 gave 49 per cent of the fruits scabby, in 1916 gave from 39 to 73 per cent scabby, and in 1917 gave from 7 to 32 per cent scabby.[60] This is in contrast to the fact that in the tests on Highmoor Farm in 11 years (See Table 10, up to 1921 inclusive) the use of only three applications kept scab down to 45 per cent in the worst year, and in two subsequent years four applications when tried gave only 3 and 17 per cent scab.

In Ohio, in 1909, "unsprayed orchards, as before, bore but very light crops of worthless, scabby culls." "Destructive insects and fungous diseases had, for ten years or more, destroyed the crops annually."[61] In 1922, 42 per cent of Ben Davis in check plots were so badly infected as to be deformed by scab, while 11 per cent were scabby in a plot with one application of Bordeaux mixture at the pink and five applications of lime-sulphur later.[62] Such severe injury has never occurred at Highmoor Farm.

In the apple growing region in Nova Scotia, about 200 miles east of southern Maine, it pays best to use copper-arsenic dust,[63] while in Massachusetts, about 200 miles southwest, this is not the case.[64] Some reason for this difference is shown by the statement by Sanders that

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[59]Longyear, B. O. Fungous diseases of fruits in Michigan. Michigan Agr. Exp. Sta. Special Bul. 25. 1904. See p. 7.

[60]Dutton, W. C. Dusting and spraying experiments with apples. Michigan Agr. Exp. Sta. Special Bul. 87. 1918. See p. 20, Table IX, Stark and Baldwin tests.

[61]Ballou, F. H. The rejuvenation of orchards. Ohio Agr. Exp. Sta. Bul. 224. 1910. See p. 117.

[62]Ballou, F. H., and I. P. Lewis. Spraying experiments in southeastern Ohio, 1922. Ohio Agr. Exp. Sta. Mo. Bul. 87-88. 1923. See p. 50.

[63]Sanders, George E. Dusting and spraying the apple. Dosch Chem. Co. Research Bul. 8. 1922. See p. 11.

[64]Doran, William L., and A. Vincent Osmun. *Op. cit.*, p. 11.

"In Nova Scotia we have greater difficulty in controlling apple scab, and our trees are so susceptible to lime-sulphur injury that we have had to abandon it as a spray. In most localities where there is plenty of sunlight we have no trouble following its use at a dilution of one to forty. In some Maritime localities like Nova Scotia, New Zealand, England and certain other sections very severe leaf injury followed by the dropping of fruit follows the application of lime-sulphur. Localities which can use lime sulphur without injury should certainly be advised to continue, as it is a cheap and convenient material to use."[65]

Also, Kelsall states that

"For many years past, most of our experiments with sprays and dusts have given at least seventy-five per cent of clean apples, and most of our check plots have given at least seventy-five per cent of blemished fruit. We had a succession of damp seasons with a rather low amount of sunlight, and in addition the spray gun was introduced. These two factors together caused lime-sulphur to give a considerable amount of injury and produced a low set of fruit, so that we had to abandon lime-sulphur. Experiments continued every year since, have shown us quite definitely that in a damp season with a small amount of sunlight we get serious injury from the use of lime-sulphur in the usual recommended strengths on certain varieties of apples. In a dry, bright season such as the past one we do not get this injury nor do we get it if the lime-sulphur is used sparingly as a mist spray."[66]

Reference to Tables 11 and 13 shows that the summer rainfall is greater in Massachusetts and Maine than in Nova Scotia, which may cause more removal of dust from the trees. Also, that the mean summer temperature or the number of days with a temperature of 80°F., or both, are higher in Maine, Massachusetts, and New Hampshire than in Nova Scotia, which would favor fungicidal action by sulphur.[67] Dusting will be discussed more fully later.

The need of a pre-pink application has been demonstrated in several regions while even with spores liberated early the pre-pink application has not been of value in Maine and Massachusetts.[68]

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[65]Sanders, G. E. Apple spraying. 18th Ann. Rpt. Com'r. Agri. Maine. 1919. See p. 201.

[66]Kelsall, A. Spraying and dusting. 20th Ann. Rpt. Com'r. Agri. Maine. 1921. See p. 106, 107.

[67]Doran, William L. *Op. cit.*, p. 7, 8.

[68]Krout, Webster S. *Op. cit.*, p. 30, 32. Doran, William L., and A. Vincent Osmun. *Op. cit.*, p. 5.

TABLE 13.

Transcript from records of temperature at selected stations in apple-growing regions.

Station	Year	Mean temperature ° F.							Number of days in which temperature reached 80° F.		
		April	May	June	July	August	September	Average	May	June	July
Kentville, N. S.	Mean normal[1]	40	49	59	66	64	57	55.8			
Lewiston, Me.	Mean normal[2]	42	54	64	69	66	59	59.0			
Fitchburg, Mass.	Mean normal[2]	46	57	66	70	68	61	61.3			
Rochester, N. Y.	Mean normal[2]	45	57	66	71	69	63	61.8			
Martinsburg, W. Va.	Mean normal[2]	51	62	72	75	74	67	66.8			
Griggsville, Ill.	Mean normal[2]	55	65	73	77	75	68	68.8			
Greenville, Me.	Mean normal[5]	36.4	49.5	58.9	65.4	62.5	55.0	54.6			
Boston, Mass.	Mean normal[5]	46.4	57.1	66.5	71.7	69.9	63.2	62.5			
Buffalo, N. Y.	Mean normal[5]	42.8	54.6	64.4	69.8	68.6	62.4	60.4			
Pittsburgh, Pa.	Mean normal[5]	51.2	62.4	70.7	74.6	72.9	66.4	66.4			
Lynchburg, Va.	Mean normal[5]	57.3	67.3	74.6	77.5	75.6	69.0	70.2			
Parkersburg, W. Va.	Mean normal[5]	53.0	63.3	71.5	75.6	73.3	66.1	67.1			
Cincinnati, O.	Mean normal[5]	52.4	63.1	71.2	75.1	73.6	67.1	67.1			
Grand Rapids, Mich.	Mean normal[5]	46.2	59.0	68.1	72.6	70.0	61.8	63.0			
Madison, Wisc.	Mean normal[5]	45.4	57.6	67.2	72.1	69.8	62.4	62.4			
Peoria, Ill.	Mean normal[5]	50.9	61.7	70.9	75.4	72.5	64.3	66.0			
Omaha, Nebr.	Mean normal[5]	51.2	62.4	71.6	76.7	74.4	66.8	67.2			
Portland, Oreg.	Mean normal[5]	51.8	56.9	62.4	66.7	66.7	61.7	61.0			
Lewiston, Me.[3]	1922								2	9	14
Ditto	1923								1	8	12
Ditto	1924								0	4	20
Ditto	Mean 1922-24								1.0	7.0	15.3
Nova Scotia	Mean 1916-20[4]								0.0	0.6	1.6
New Hampshire	Mean 1916-20[4]								2.92	7.6	16.52
Virginia	Mean 1916-20[4]								7.20	14.8	18.60

[1]Data in script from the Entomological Laboratory, Annapolis Royal, N. S., Feb., 1925.
[2]Data from Henry, Alfred Judson. Climatology of the United States. U. S. Dept. Agri. Weather Bur. Bul. Q. 1906. See p. 130, 151, 184, 746, and 689.
[3]Data in script from the Weather Bureau, Boston, Mass.
[4]Data from Table VI, Doran, William L., Op. cit.
[5]Based on records of 30 or more years of observations. Data from Agricultural Yearbook 1923. U. S. Dept. Agri. Table 736.

This application will be discussed more fully in the next section of this bulletin.

The preceding considerations show why results obtained elsewhere sometimes may not be strictly applicable to the apple scab problem in Maine. However, in the absence of recent experimental results in Maine orchards outside of Highmoor Farm,[69] any available help from the work in other regions should be used as far as possible, with reference to the kind of tests being made here. The following review of work done elsewhere is not complete but may be of use especially in view of the marked changes in apple scab research and methods of control since the last Maine Station bulletin on apple scab was issued.

CONCLUSIONS ON THE PRE-PINK APPLICATION.

As has been indicated on p. 143, the discharge of ascopores (from the scab fungus overwintering in the fallen leaves) before the time for the pre-pink application is common in the United States. Its wide-spread occurrence and importance is shown in the following pages of this section of the bulletin. It therefore would not be surprising to find a pre-pink application of use in Maine. Its need in 1919 was indicated by the results obtained (p. 134). However, as has already been indicated in this bulletin, the test at Highmoor Farm in 1924 did not give any scab control value to the pre-pink application, even though ascospores were being liberated and causing infection at the time.

In this test a comparison was made, as has been described, between a schedule with two applications after the delayed-dormant stage and before the opening of the blossoms, on the one hand, and a schedule with only the second of these two applications, on the other hand. Neither of these schedules is exactly like the old one wherein a single application was made before blossoming. Such an application was made sometime "before the flower buds open and after they are swelled so as to show a trace of pink color"[70] and therefore might overlap somewhat both the

[69]The last ones were reported briefly in 1908, relating to control of scab in McIntosh by means of Bordeaux mixture. (Munson, W. M. Orchard notes, 1907: Maine Agr. Exp. Sta. Bul. 155. 1908. See p. 143.)

[70]Woods, Chas. D. Summaries of Station Work No. 1. Apple studies. Maine Agr. Exp. Sta. Miscel. Publ. 488. 1913. See p. 18.

pre-pink and pink as to the corresponding stages of bud development in the 1924 tests.

In Indiana in 1918 and 1919, on Ben Davis the omission of a pre-pink spray was followed by the occurrence of scab on from 48 to 74 per cent of the fruits, in spite of three or four applications. In 1919 about four weeks elapsed between the pink and calyx applications, during which conditions were favorable for scab infection. With the pre-pink added in 1920, 1921, and 1922, when the check fruits were 95 to 100 per cent scabby, spray reduced scab to from 35 to 48 per cent.[71] In Maryland "experiments and demonstrations have demonstrated that scab can be controlled by three applications, the first one being the delayed dormant, the second the pre-pink or pink, and the third, the calyx application. Of course other applications are necessary for the control of other insects and diseases."[72]

Results generally similar to those obtained on Highmoor Farm in 1924 are seen in the report of experiments made in Massachusetts in 1922 and 1923.[73] The need of a pre-pink has been demonstrated in Michigan.[74] In New Hampshire in 1922, control of scab on McIntosh with Bordeaux mixture and copper acetate was better in an orchard receiving a pre-pink application in addition to the pink, calyx and two-weeks, than in another orchard with only the three applications after the pre-pink.[75]

In New York in 1902, an application of dormant-strength lime-sulphur was delayed until "in many cases the buds had already burst and in some cases the leaves were well out, while in others only the tips of the young leaves were beginning to appear." "Although the trees received no treatment except with the lime-sulphur-salt wash, the fruit from the treated trees was practically free from scab, while that of the checks was badly

[71]Cullinan, F. P., and Clarence E. Baker. Liquid lime-sulphur versus sulphur dust for apple spraying. Indiana Agr. Exp. Sta. Bul. 283. 1924.

[72]Jehle, R. A. Apple scab and its control. Trans. Peninsula Hort. Soc. 1924. Delaware State Bd. Agri. Bul. Vol. 13, No. 3:9-11. See p. 9.

[73]Krout, Webster S. *Op. cit.* Doran, William L., and A. Vincent Osmun. *Op. cit.,* p. 4-5, 12.

[74]Dutton, W. C., and Stanley Johnston. *Op. cit.,* p. 3-6.

Bennett, C. W. Apple scab and its control. Michigan Agr. Exp. Sta. Quar. Bul. February, 1923. p. 130-134.

[75]New Hampshire Agr. Exp. Sta. Bul. 208:24. Rpt. for 1922. Work done by Butler and Doran.

infested."[76] Whetzel states that in New York "the delayed dormant application is vital to successful scab control at least three years out of five. Effective protection at this time generally means clean fruit and a minimum of applications later."[77]

In Ohio a pre-pink application with Bordeaux mixture did not add to scab control.[78] There "the pre-pink was of practically no value," because even with ascospores being discharged by April 4 and the pink stage being reached by May 4, weather conditions were not favorable for infection before the pink spray. In Oregon, where the first ascospore discharge was observed a month earlier than had been previously recorded, a delayed dormant application added about 12 per cent to the amount of scab-free fruit.[79] There, in the preceding season, the first infection was apparent on the leaves, petals, and calyx lobes, and was reduced by a delayed dormant application, thus reducing the sources and amount of fruit infection later in the summer.[80] In Pennsylvania, "the value of at least one spray previous to the so-called 'pink spray' appears thoroughly demonstrated."[81] Here "this application should, as a rule, be at the time of the delayed dormant." "If early infections are not prevented the problem of control becomes increasingly more difficult as the season advances."[82]

In Virginia in 1920, the period of greatest ascospore discharge occurred so late that the most important single application was not the pre-pink, pink, or calyx, but was the ten-day. This season was regarded as unusual in respect to the lateness of

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[76]Lowe, V. H., and P. J. Parrott. San Jose scale investigations. IV. New York Geneva Agr. Exp. Sta. Bul. 228. Rep. in 21st Ann. Rpt. 1902. See p. 296-297.

[77]Dusting apples in New York. Trans. Peninsula Hort. Soc. 1924. Delaware State Bd. Agri. Vol. 13, No. 3:19-27.

[78]Ballou, F. H., and I. P. Lewis. Spraying experiments in southeastern Ohio. Ohio Agr. Exp. Sta. Mo. Bul. 99-100. 1924. See p. 41.

Stover, W. G., and H. W. Johnson. First progress report on the study of apple scab under Ohio conditions. Phytopath. 14:60. 1924. (Abst.)

[79]Childs, Leroy. New facts regarding the period of ascospore discharge of the apple scab fungus. Oregon Agr. Exp. Sta. Bul. 143. 1917. See p. 3 and 10.

[80]Jackson, H. S., and J. R. Winston. *Op. cit.*, p. 13-14.

[81]Thurston, H. W. Spraying and dusting experiment for control of apple scab. In Pennsylvania Agr. Exp. Sta. Bul. 188. (Rpt.) 1924. See p. 16.

[82]Thurston, H. W., Jr., R. D. Walton, and F. N. Fagan. *Op. cit.*, p. 19.

scab infection.[83] On Highmoor Farm, omission of the pink spray, with no application in any plot before the pink, had no effect in reducing scab control in 1914,[84] 1915,[85] and 1916,[86] years in which the scab percentage in unsprayed plots were respectively 13, 5, and 39. Referring to Virginia again, in 1922 the pink application there was the most important in controlling a bad scab infection but in 1923 there was practically no scab even on the unsprayed trees because of low humidity at the times of early-season ascospore discharge, and because of resistant maturity of foliage and fruits later.[87] In Washington, especially in the western part of the state, scab infects early as in Oregon, appearing on the blossom parts.[88] The same is true in Wisconsin.[89]

It is seen from the preceding that it is no longer regarded as true that the ripening of the winter spores

> "is so timed that they are ripe just at the time that the blossoms are about to open. That is to say, if the blossoms open a week earlier in a given year, the spores are ripe a week earlier, and if the blossoms open a week later the spores are ripe a week later. The same weather conditions which bring open the blossoms also ripen and bring about the distribution of the spores. There is no object whatever in spraying the trees when they are dormant for the control of apple scab. The spores are not ripe or distributed at that period."[90]

Since that time it has become apparent that the time of discharge of winter spores varies considerably from season to season in one place and from one place to another in one season, relative to the

[83]Fromme, F. D., G. S. Ralston, and J. F. Eheart. Dusting experiments in peach and apple orchards in 1920. Virginia Agr. Exp. Sta. Bul. 224. 1921. See p. 9.

[84]Morse, W. J., and M. Shapovalov. Apple spraying experiments in 1914. Maine Agr. Exp. Sta. Bul. 240. 1915. See p. 188.

[85]Morse, W. J. Spraying experiments and apple diseases in 1915. Maine Agr. Exp. Sta. Bul. 252. 1916. See Table 1.

[86]Morse, W. J. Apple spraying experiments in 1916 and 1917. Maine Agr. Exp. Sta. Bul. 271. 1918. See Table 1.

[87]Schneiderhan, F. J., and F. D. Fromme. *Op. cit.*, p. 20-24.

[88]Zundel, George L. Control of apple scab. Washington Agr. Col. Ext. Bul. 99. 1923. See p. 3.

[89]Keitt, G. W., and L. K. Jones. Sepal infection in relation to the seasonal development and control of apple scab. Phytopathology 14:36. 1924

[90]11th Ann. Rpt. Com'r Agri. Maine 1912. Ann. Rpt. State Pomol. Soc. 1912-13. See p. 112. Statement by a leading pathologist, made of course without the knowledge we now have.

time of blossoming. There are two ways to meet this difficulty of variability in time of discharge. One way is always to start spraying early enough to prepare the trees for the earliest known discharge. The other is to make use of community-serving specialists such as now, in some regions, give advice as to the probable profits to be derived from applying or from dispensing with any early application that is in question.

CONCLUSIONS ON DUSTING.

It is too early to draw a definite conclusion from experiments on Highmoor Farm as to dusting. As has been pointed out, dusting there has sometimes been equal to spraying but not always, and the reasons for differences are not yet clear. With dusting as with spraying, at least ten years' work is needed for reliable conclusions from results on one farm and such conclusions are not necessarily strictly applicable on other farms.

The same questions as for spraying are of interest to the practical grower in regard to dusting, referring to possibility of effectiveness, reasons for any inefficiency, and profits derived from effective use. Also the thought arises of a comparison of dusting with respect to the somewhat older and more general practice of spraying. Even with the necessity of making due allowance for the effect of differences between regions in regard to climate, it is probably of some value to consider the results reported elsewhere on dusting.

As has been pointed out by Whetzel, attempts to develop a satisfactory dust had not succeeded up to 1910. Materials used up to that time were different from those that have been tested at Highmoor Farm, and will not be discussed in the following brief review.[91]

Experiments conducted in Connecticut in 1923, with the dates for the pre-pink, pink, and calyx applications all advanced two weeks in comparison with the dates at Highmoor Farm, gave the following results that are of interest here.

"The sulphur-arsenate dust proved more effective against scab than the copper-arsenic dust. McIntosh is a variety much subject to scab attack, and though it was seemingly not a serious scab season, the check or un-

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[91]Dusting apples in New York. Trans. Peninsula Hort. Soc. 1924. Delaware State Bd. Agri. Vol. 13, No. 3:19-27.

treated trees showed 96.5 per cent. of scab injury. Where copper-arsenic dust alone was applied this percentage was reduced only to 74, but where sulphur-arsenate dust was substituted for one application the scab injury was cut to 54, and where sulphur-arsenate dust was substituted for two applications, scab injury was still further reduced to 27 per cent. As scab control was the chief aim on this variety, the copper-arsenic dust alone proved very inefficient. On the other hand, where sulphur-arsenate dust was applied in every application scab injury did not go much above seven per cent., while on the sprayed trees it was less than four per cent."[92]

The same report concludes, in regard to a comparison between dusting and spraying, after conducting experiments for the four years 1920 to 1923 that "the liquid spray has given somewhat better results in the control of injurious insects and fungi on apple trees in Connecticut than any of the dust mixtures. . . . . The sulphur-arsenate dust gave fair control of insect pests and of fungous diseases, particularly apple scab. . . . .Where the water supply is not convenient and help is difficult to obtain, the dust method might be followed advantageously." In Delaware in 1919, spray controlled scab well while sulphur dust gave poor control.[93] In Illinois in 1916, sulphur-arsenate dust did not control scab on Ben Davis as well as spray, the best results with dust being a reduction of scab from 53 per cent in the checks to from 6 to 23 per cent while liquid spraying reduced scab from 53 and 95 per cent in the checks to 1 per cent.[94] Other results from the same state for 1915, 1917, and 1918 appear more favorable to dust than to spray.[95]

In Indiana on Ben Davis, with schedules that allowed from 35 to 75 per cent scab with lime-sulphur spray, sulphur lead-arsenate dust gave as good control in only one year of five. The scab percentage on the fruits averaged, for the five years 1918 to 1922, 48 per cent with spray and 64 per cent with dust. The checks bore very little fruit, and only 2 per cent of it was not

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[92]Zappe, M. P., and E. M. Stoddard. Experiments in dusting versus spraying in Connecticut apple orchards in 1923. Connecticut Agr. Exp. Sta. Bul. 256:267-274. 1924. See p. 271.

[93]Leach, B. R., and John W. Roberts. The control of the codling moth and apple scab in Delaware. Trans. Peninsula Hort. Soc. 1920. Delaware State Bd. Agri. Bul. Vol. 9, No. 3:14-22. See p. 20.

[94]Gunderson, A. J., and W. S. Brock. Field experiments in spraying apple orchards in 1916. Illinois Agr. Exp. Sta. Circ. 194, 1917. See p. 6-9.

[95]Whetzel, H. H. The present status of dusting. Reprint Proc. 2nd. Ann. Meeting New York State Hort. Soc. 1920. See p. 56, Table IV.

scabby. In these tests "scab was more serious on the foliage of dusted plots" and "in general the fruit was smaller on the dusted trees, a condition partially attributable to early scab defoliation of the spurs." On the other hand, the spray caused more severe injury by burning and russeting than the dust.[96] In Maryland in 1919, a year of serious injury by scab, control was inferior by means of dusting, with a sulphur type of dust, as compared with spray.[97]

In Massachusetts, "copper-lime-arsenate dust controlled scab more effectively than the sulphur dusts, as in three of four orchards it gave a higher percentage of clean and marketable fruit. However, it cannot be recommended for apples on account of the russeting of the fruit and the burning of the foliage."[98] A later report concludes that in Massachusetts "sulphur dust controlled apple scab satisfactorily when it was applied five times beginning with the pre-pink application, but not when it was applied four times beginning with the pink application. Sulfur dust throughout the dusting season controlled apple scab as satisfactorily as when copper dust was substituted for sulfur dust for the applications before the flower buds opened."[99] These conclusions were confirmed by the work done in 1924.[100]

In Michigan, copper sulphate (Sanders) dust was inferior to sulphur dust, which controlled scab as well as spray, both allowing about 20 per cent.[101] Dutton in Michigan, in the only test reported by him wherein spraying in 1915, 1916, or 1917 controlled scab satisfactorily and a check count was made as to uncontrolled scab, with five dust applications controlled scab (6.4 per cent) the same as with four spray applications.[102] Otherwise, where spray did not control scab well, dust usually but not always gave still poorer control. He reports further that in 1918 and 1919, dusting controlled scab as well as spraying did, or

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[96]Cullinan, F. P., and Clarence E. Baker. *Op. cit.*

[97]Travers, W. C. Report of dusting investigations. Trans. Peninsula Hort. Soc. 1920. Delaware State Bd. Agri. Bul. Vol. 9, No. 3:39-43. See p. 40.

[98]Krout, Webster S. *Op. cit.*, p. 37 (Italics in the original omitted.)

[99]Doran, William L., and A. Vincent Osmun. *Op. cit.*, p. 12, 13.

[100]Doran, W. L. Experiments on the control of apple scab and black rot and spray injury in 1924. Massachusetts Agr. Exp. Sta. Bul. 222. 1925.

[101]Dutton, W. C., and Stanley Johnston. *Op. cit.*, p. 8-10.

[102]Dutton, W. C. *Op. cit.*, p. 11-13, 20.

better, in six comparative tests in which the scab in the checks ranged from 1 to 62 per cent. The spraying was done with a gun at a pressure when stated of only 225 pounds or less, and allowed over 5 per cent scab whenever the checks showed over 15 per cent.[103] In Minnesota in 1919, dust was reported on favorably in comparison with Bordeaux in regard to scab control.[104] In New Jersey, dust is reported to have controlled scab poorer than spray in 1913, but better in 1914, 1919, and 1920.[105]

In New York, experimental dusting with sulphur was begun in 1911 and continued through 1913, with "encouraging results."[106] It was then repeated in 1914 with the results in Baldwins as good as or better than with spraying, and with the results in Ben Davis poorer than the poor results obtained with spraying.[107] In 1915 "the experiments show. . . .that powdered sulfur applied dry does not adhere as well as sulfur applied in liquid form as lime-sulfur solution. . . . .In every case but one in which scab was a factor, the percentage of scab on the dusted plats was greater than on the sprayed plats, though in some cases the difference is insignificant." However, the control with dust was so good, and there were such other advantages, that dust was recommended for certain conditions.[108] In 1922,[109 110] sulphur dust was inferior to lime-sulphur spraying and copper dust was still more inferior, in one orchard of Greenings, while in another orchard of the same variety dust of both kinds was equally in-

[103]Dutton, W. C. Dusting and spraying experiments of 1918 and 1919. Michigan Agr. Exp. Sta. Special Bul. 102. 1920. See p. 8, 11, 21, and 25.
See text and footnote [22] on p. 145.

[104]Whetzel, H. H. *Op. cit.*, p. 58.

[105]Headlee, Thomas J. Dusting vs. spraying for insect control. Trans. Peninsula Hort. Soc. 1921. Delaware State Bd. Agri. Vol. 10, No. 3:51-60. See p. 55.

[106]Blodgett, F. M. Experiments in the dusting and spraying of apples. New York Cornell Agr. Exp. Sta. Bul. 340. 1914. See p. 179.

[107]Reddick, Donald, and C. R. Crosby. *Op. cit.*, p. 69, 80, and 85.

[108]Reddick, Donald, and C. R. Crosby. Dusting and spraying experiments with apples. New York Cornell Agr. Exp. Sta. Bul. 369. 1916. See p. 351-352.

[109]Parrott, P. J., F. C. Stewart, and Hugh Glasgow. Spraying and dusting experiments with apples in 1922. New York Geneva Agr. Exp. Sta. Circ. 63. 1922.

[110]Conclusions given here are drawn directly from the tables in this series of Geneva Station publications, none being attempted by the Geneva writers.

ferior to spraying and in a Rome orchard sulphur dust gave practically the same good control as spray. In 1923[110 111] in the same orchards, respectively, sulphur dust controlled scab well while copper dust did not; copper dust gave good control while sulphur dust and spray gave still better; and sulphur dust gave good control but was inferior to spray. In 1924[110 112] in the same orchards, respectively, with scab unusually destructive, dust of both kinds gave good control; spray controlled well with five applications of 12 to 15 gallons per tree while dust of the two kinds did so only with sixteen applications of 2 to 5 pounds per tree, being inferior to spray with the same number of applications, with the copper dust somewhat more inferior than the sulphur dust; spray gave good control with dust of both kinds about equally inferior. In New York in 1923, russeting in Greenings was most severe with copper dusts, and was less severe with sulphur dusts than with lime-sulphur. There was foliage injury with lime-sulphur and with copper dusts, but none with sulphur dusts or with "wettable sulphur" spray.[113]

In Ohio "a casual comparison of results with scab nearly always led to the conclusion that dusting was not controlling scab quite so well as spraying," with counts confirming this impression, except one in 1917 where sulphur dust equalled lime-sulphur spray.[114] In Oregon in 1916, six applications of sulphur dust controlled scab about as well as four applications of lime-sulphur spray, reducing the percentage from 60 to 4 per cent. In 1917, about 24 per cent scab was practically eliminated by four applications of dust or three of spray. The prevalence of wind made dust generally impractical there.[115]

In Pennsylvania, "lime sulphur spray again proved somewhat more effective in controlling scab than dust, though dust

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[111]Parrott, P. J., F. C. Stewart, and Hugh Glasgow. Spraying and dusting experiments with apples in 1923. New York Geneva Agr. Exp. Sta. Circ. 70. 1923.

[112]Parrott, P. J., Hugh Glasgow, and F. C. Stewart. Spraying and dusting experiments with apples in 1924. New York Geneva Agr. Exp. Sta. Circ. 78. 1924.

[113]Parrott, P. J. Some side lights on spray injuries to apple fruits and foliage. Jour. Econ. Entom. 17:267-274. 1924.

[114]Gossard, H. A. Dust spraying. Ohio Agr. Exp. Sta. Mo. Bul. 53. 1920. See p. 152.

[115]Childs, Leroy. Comparative results in controlling codling moth. Better Fruit Vol. 13, No. 9, p. 5, 41-46. 1919. See p. 9.

is promising."[116] This refers to various kinds of sulphur dust, as "copper dusts have never given as good results as the sulphur dust mixtures."[117] In Virginia in 1917, a sulphur-lime dust gave about as good control of scab as spray on two varieties but not on Ben Davis, on which variety the scab infection was heavier (62 per cent in the checks as against 22 to 38 per cent in the other varieties.)[118] In 1920, sulphur dust gave as good control as spray while copper dusts did not do so and also caused some russeting. Also the sulphur dust caused no russeting but the spray did.[119] Experiments in 1919 and 1920 "indicated that sulphur dust is not so effective as either the lime sulphur spray or the Bordeaux spray for control of apple scab in West Virginia orchards where the disease is severe."[120] In Wisconsin with dust "in some cases very good control of the scab disease was obtained, while in others it was very inadequate."[121]

Tests made by the U. S. Department of Agriculture in Michigan in 1915, 1916, and 1917, in Virginia in 1918, and in Arkansas in 1918, with various kinds of sulphur dusts gave scab percentages intermediate between those for liquid and checks.[122]

In British Columbia, sulphur dust was inferior to copper dust and both were inferior to liquid lime-sulphur.[123] In New Brunswick in 1922 and 1923, copper dust controlled scab nearly as well

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[116]Thurston, H. W. *Op. cit.*

[117]Thurston, H. W., Jr., R. D. Walton, and F. N. Fagan. *Op. cit.*, p. 19.

[118]Fromme, F. D., and W. J. Schoene. Dusting and spraying for apple scab and codling moth. Rpt. Virginia State Entom. and Plant Path. 1916-17:22-26. See p. 26.

[119]Fromme, F. D., G. S. Ralston, and J. F. Eheart. *Op. cit.*, p. 8-10.

[120]Giddings, N. J. Orchard dusting versus spraying. Jour. Econ. Entom. 14:225-230. 1921. See p. 227.

[121]Wisconsin Agr. Exp. Sta. Bul. 352. 1923. Ann. Rpt. for 1921-1922. See p. 60.

[122]Quaintance, A. L. Dusting versus spraying of apples. Jour. Econ. Entom. 14:220-225. 1921.

[123]Hunt, E. C. Report of Assistant Horticulturist and Inspector of Fruit Pests, East and West Kootenay districts. Ann. Rpt. Dept. Agric. (British Columbia) 14:36-39. 1920. (As abstracted in Bot. Abst. 7:183. Entry 1233.)

Eastham, J. W., and E. C. Hunt. Spraying for apple scab in the Kootenays. Agric. Jour. (British Columbia) 6:38-39. 1921. (As abstracted in Bot. Abst. 9:64-65. Entry 432.)

Eastham, J. W. Fungicides. Sci. Agr. 3:190-191. 1923. (As abstracted in Exp. Sta. Rec. 51:548.)

as 3-10-40 Bordeaux and produced less fruit russeting. Sulphur compounds were substituted for the copper compounds in the calyx application.[124] In Nova Scotia, copper dust has given satisfaction,[125] apple scab being usually well controlled where the infestation is not over 40 per cent.[126] In Ontario without more applications than with spray, dust gave good results where scab infection was slight but fell down badly where scab was bad, copper dust being slightly poorer in control than sulphur dust.[127] "In Quebec, orchard dusting has developed rapidly in the past 8 years and has proved as efficient as spraying in controlling apple scab."[128] In 1917 and 1918, with 80 and 95 per cent scab respectively in the controls, dust and spray practically eliminated the disease, but in 1919 spray reduced scab only from 93 to 21 per cent and a cheaper dust, containing more filler, eliminated only a third of the scab.[129]

With our present knowledge and materials it would seem that with the same number of applications there is more chance for disappointment in trying dusting than in trying spraying for the control of apple scab in Maine, though apparently there is a chance for success with both methods under some conditions.

CONCLUSIONS ON THE USE OF A CASEIN SPREADER.

On Highmoor Farm the addition of a commercial casein spreader to lime-sulphur did not improve an already good control of scab when tested in 1923 and 1924. Such a spreader can also be added to dust.

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[124]Bailey, C. F. Report of the Superintendent for the year 1922. Dominion Experimental Station, Fredericton, N. B. See p. 34.

Bailey, C. F. Report of the Superintendent for the year 1923. Dominion Experimental Station, Fredericton, N. B. See p. 28-29.

[125]Sanders, George E. *Op. cit.* (Dosch Bul. 8), p. 11.

[126]Brittain, W. H. Five years' spraying and dusting experiments. Ann. Rpt. Fruit Growers' Assoc. Nova Scotia 1923:53-72. (As abst. in Bot. Abs. 13:553. Entry 3715.)

[127]Ross, William A. Results of dusting and spraying in Ontario. In Crop Protection Digest Bul. 2. Crop Prot. Inst. Washington, D. C. 1922. See p. 27.

[128]Petch, C. E. Spraying versus dusting. Sci. Agric. (Canada) 1:171-172. 1921. (As abst. in Bot. Abst. 10:39. Entry 238.)

[129]Petch, C. E. Spraying vs. dusting. Quebec Soc. Prot. Plants 13th Ann. Rpt. 1920-1921. P. 68-72.

In Massachusetts "the addition of calcium caseinate spreader to the liquid spray was followed by a very slight decrease in the percentage of scabby fruit. The addition of calcium caseinate spreader to sulfur dust did not result in a smaller percentage of scabby fruit than when sulfur dust was used alone."[130] In 1924, a casein spreader added to lime-sulphur spray did not increase scab control and did not reduce leaf injury, but it reduced fruit russet in the Gravenstein variety.[131] In Missouri, a casein spreader did not improve the control of apple scab by lime-sulphur.[132]

Negative results were given in New York in 1922, 1923, and 1924, by tests with a calcium caseinate spreader added to lime-sulphur and in 1923 with such spreader added to sulphur-lead arsenate dust. This spreader in 1922 improved the control given by a copper-lime dust.[110 133] In New York in 1923, the addition of calcium caseinate to lime-sulphur reduced russeting but had no evident effect on burning of the foliage. The russeting was in part of a netted type, but even this is becoming important in commercial grading.[134] In Pennsylvania "calcium caseinate used at various strengths in lime-sulphur sprays has not had the effect of increasing the fungicidal value of these sprays."[135]

In Virginia in 1922, a prepared calcium caseinate spreader (Kayso) did not improve the control of scab by lime-sulphur.[136] A repetition of the test lead to the same conclusion in 1923.[137] In Wisconsin, calcium caseinate gave a slight increase to the effectiveness of lime-sulphur and bordeaux sprays.[138]

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[130] Doran, William L., and A. Vincent Osmun. *Op. cit.*, p. 13.

[131] Doran, W. L. *Op. cit.*

[132] Swartwout, H. G. *Op. cit.*

[133] Parrott *et al.* *Op. cit.* (Circ. 63, 70, and 78.)

[134] Parrott, P. J. Some side lights on spray injuries to apple fruits and foliage. Jour. Econ. Entom. 17:267-274. 1924.

[135] Thurston, H. W., Jr., R. D. Walton, and F. N. Fagan. *Op. cit.*, p. 20.

[136] Stearns, L. A., and W. S. Hough. Spreader tests on apples and peaches. Jour. Econ. Entomol. 16:198-201. 1923.

[137] Stearns, L. A., and W. S. Hough. Spreader tests on apples and peaches: a second report. Jour. Econ. Entom. 17:274-278. 1924.

[138] Wisconsin Agr. Exp. Sta. Bul. 352. 1923. Ann. Rpt. 1921-1922. See p. 60.

In Ontario in 1922, Kayso caused burning as on Highmoor Farm in 1924, and report is made of similar results in New York and "in a number of other places in the United States."[139]

The chief value of a casein spreader seems to be in a reduction of the amount of russeting on the fruits of certain susceptible varieties.

THE APPLICATION OF PRINCIPLES OF SCAB CONTROL BY THE APPLE GROWER.

The most profitable application of definite conclusions by an apple grower in his own orchard has been shown in the preceding sections to be difficult when attempted on the basis of results of experiments performed in other orchards. Such experiments, together with numerous general observations, can go some distance in guiding the apple grower by establishing a general regional standard, but this general standard can be expected to give only general or average results. To get the most profit the general standard needs modification to suit each particular orchard or season, with attention directed also to the susceptibility of the variety concerned.[140] Such modification of a regional standard can proceed along two general lines—individual study and community cooperation.

In this connection specific mention may be made of attempts by the individual grower to experiment somewhat, technical advice regarding the seasonal conditions of the overwintering stage of scab, spray rings, cost accounts, cooperation in marketing, standardization of grading, and economic surveys.

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[139]Caesar, L. *Op. cit.*, p. 30-31.

[140]"Fruit can not be grown successfully by 'rule-of-thumb' methods of procedure. The fruit grower who best understands the principles involved and applies them wisely is the one who usually succeeds, because he best meets the conditions of nature with which he contends." (Gould, H. P. *Op. cit.*, p. ii.)